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MOLECULAR AND CELLULAR BIOLOGY, vol. 5, no. 5, May 1985, pages 1111-1121, American Society for Microbiology; S.B. ELLIS et al.: "Isolation of alcohol oxidase and two other methanol regulatable genes from the yeast *Pichia pastoris*"

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## Description

This invention relates to the field of recombinant DNA biotechnology. In one of its aspects, the invention relates to DNA fragments which regulate the transcription of DNA into messenger RNA, and the initiation and termination of the translation of messenger RNA into protein. In another aspect, the invention relates to expression vectors which incorporate the above-described DNA fragments. In yet another aspect, the invention relates to novel microorganisms transformed with the above-described expression vectors. In a further aspect, the invention relates to the production of polypeptides.

## Background

As recombinant DNA technology has developed in recent years, the controlled production by microorganisms of an enormous variety of useful polypeptides has become possible. Many eukaryotic polypeptides, such as for example human growth hormone, leukocyte interferons, human insulin and human proinsulin have already been produced by various microorganisms. The continued application of techniques already in hand is expected in the future to permit production by microorganisms of a variety of other useful polypeptide products.

The basic techniques employed in the field of recombinant DNA technology are known by those of skill in the art. The elements desirably present in order for a host microorganism to be useful for the practice of recombinant DNA technology include, but are not limited to:

- (1) a gene encoding one or more desired polypeptide(s) and provided with adequate control sequences required for expression in the host microorganism,
- (2) a vector, usually a plasmid, into which the gene can be inserted. The vector serves to guarantee transfer of the gene into the cell and maintenance of DNA sequences in the cell as well as a high level of expression of the above-mentioned gene, and
- (3) a suitable host microorganism into which the vector carrying the desired gene can be transformed, where the host microorganism also has the cellular apparatus to allow expression of the information coded for by the inserted gene.

A basic element employed in recombinant DNA technology is the plasmid, which is extrachromosomal, double-stranded DNA found in some microorganisms. Where plasmids have been found to naturally occur in microorganisms, they are often found to occur in multiple copies per cell. In addition to naturally occurring plasmids, a variety of man-made plasmids, or hybrid vectors, have been prepared. Included in the information encoded in plasmid DNA is that required to reproduce the plasmid in daughter cells, i.e., an autonomously replicating sequence or an origin of replication. One or more phenotypic selection characteristics must also be included in the information encoded in the plasmid DNA. The phenotypic selection characteristics permit clones of the host cell containing the plasmid of interest to be recognized and selected by preferential growth of the cells in selective media.

The utility of plasmids lies in the fact that they can be specifically cleaved by one or another restriction endonuclease or restriction enzyme, each of which recognizes a specific, unique site on the plasmid DNA. Thereafter, homologous genes, heterologous genes, i.e., genes derived from organisms other than the host, or gene fragments may be inserted into the plasmid by endwise joining of the cleaved plasmid and desired genetic material at the cleavage site or at reconstructed ends adjacent to the cleavage site. The resulting recombinant DNA material can be referred to as a hybrid vector.

DNA recombination is performed outside the host microorganism. The resulting hybrid vector can be introduced into the host microorganism by a process known as transformation. By growing the transformed microorganism, large quantities of the hybrid vector can be obtained. When the gene is properly inserted with reference to the portions of the plasmid which govern transcription and translation of the encoded DNA message, the resulting hybrid vector can be used to direct the production of the polypeptide sequence for which the inserted gene codes. The production of polypeptide in this fashion is referred to as gene expression.

Gene expression is initiated in a DNA region known as the promoter region. In the transcription phase of expression, the DNA unwinds exposing it as a template for synthesis of messenger RNA. RNA polymerase binds to the promoter region and travels along the unwound DNA from its 3' end to its 5' end, transcribing the information contained in the coding strand into messenger RNA (mRNA) from the 5' end to the 3' end of the mRNA. The messenger RNA is, in turn, bound by ribosomes, where the mRNA is translated into the polypeptide chain. Each amino acid is encoded by a nucleotide triplet or codon within what may be referred to as the structural gene, i.e., that part of the gene which encodes the amino acid sequence of the expressed product. Since the nucleotides code for the production of each amino acid, it is possible for a

nucleotide sequence to be "read" in three different ways. The specific reading frame which encodes the desired polypeptide product is referred to as the proper reading frame.

After binding to the promoter, RNA polymerase first transcribes a 5' leader region of mRNA, then a translation initiation or start codon, followed by the nucleotide codons within the structural gene itself. In order to obtain the desired gene product, it is necessary for the initiation or start codon to correctly initiate the translation of messenger RNA by the ribosome in the proper reading frame. Finally, stop codons are transcribed at the end of the structural gene which cause any additional sequences of mRNA to remain untranslated into peptide by the ribosomes, even though additional sequences of mRNA had been formed by the interaction of RNA polymerase with the DNA template. Thus, stop codons determine the end of translation and therefore the end of further incorporation of amino acids into the polypeptide product. The polypeptide product can be obtained by lysing the host cell and recovering the product by appropriate purification from other microbial protein, or, in certain circumstances, by purification of the fermentation medium in which the host cells have been grown and into which the polypeptide product has been secreted.

In practice, the use of recombinant DNA technology can create microorganisms capable of expressing entirely heterologous polypeptides, i.e., polypeptides not ordinarily found in, or produced by, a given microorganism — so called direct expression. Alternatively, there may be expressed a fusion protein, i.e., a heterologous polypeptide fused to a portion of the amino acid sequence of a homologous polypeptide, i.e., polypeptides found in, or produced by, the wild-type (non-transformed) host microorganism — so called indirect expression. With indirect expression, the initially obtained fusion protein product is sometimes rendered inactive for its intended use until the fused homologous/heterologous polypeptide is cleaved in an extracellular environment. Thus, for example, cyanogen bromide cleavage of methionine residues has yielded somatostatin, thymosin alpha 1 and the component A and B chains of human insulin from fused homologous/heterologous polypeptides, while enzymatic cleavage of defined residues has yielded beta endorphin.

Up to now, commercial efforts employing recombinant DNA technology for producing various polypeptides have centered on *Escherichia coli* as a host organism. However, in some situations *E. coli* may prove to be unsuitable as a host. For example, *E. coli* contains a number of toxic pyrogenic factors that must be eliminated from any polypeptide useful as a pharmaceutical product. The efficiency with which this purification can be achieved will, of course, vary with the particular polypeptide. In addition, the proteolytic activities of *E. coli* can seriously limit yields of some useful products. These and other considerations have led to increased interest in alternative hosts, in particular, the use of eukaryotic organisms for the production of polypeptide products is appealing.

The availability of means for the production of polypeptide products in eukaryotic systems, e.g., yeast, could provide significant advantages relative to the use of prokaryotic systems such as *E. coli* for the production of polypeptides encoded by recombinant DNA. Yeast has been employed in large scale fermentations for centuries, as compared to the relatively recent advent of large scale *E. coli* fermentations. Yeast can generally be grown to higher cell densities than bacteria and are readily adaptable to continuous fermentation processing. In fact, growth of yeast such as *Pichia pastoris* to ultra-high cell densities, i.e., cell densities in excess of 100 g/L, is disclosed by Wegner in U.S. 4,414,329 (assigned to Phillips Petroleum Co.). Additional advantages of yeast hosts include the fact that many critical functions of the organism, e.g., oxidative phosphorylation, are located within organelles, and hence not exposed to the possible deleterious effects of the organism's production of polypeptides foreign to the wild-type host cells. As a eukaryotic organism, yeast may prove capable of glycosylating expressed polypeptide products where such glycosylation is important to the bioactivity of the polypeptide product. It is also possible that as a eukaryotic organism, yeast will exhibit the same codon preferences as higher organisms, thus tending toward more efficient production of expression products from mammalian genes or from complementary DNA (cDNA) obtained by reverse transcription from, for example, mammalian mRNA.

The development of poorly characterized yeast species as host/vector systems is severely hampered by the lack of knowledge about transformation conditions and suitable vectors. In addition, auxotrophic mutations are often not available, precluding a direct selection for transformants by auxotrophic complementation. If recombinant DNA technology is to fully sustain its promise, new host/vector systems must be devised which facilitate the manipulation of DNA as well as optimize expression of inserted DNA sequences so that the desired polypeptide products can be prepared under controlled conditions and in high yield.

#### Objects of the Invention

An object of our invention is therefore a novel regulatory region responsive to the presence of methanol.

A further object of the invention is a novel catabolite sensitive regulatory region which is responsive to the presence of some carbon sources but which is not responsive to the presence of other carbon sources.

Another object of the invention is a novel regulatory region responsive to carbon source starvation.

Yet another object of our invention is novel vectors capable of expressing an inserted polypeptide coding sequence.

Still another object of our invention is novel yeast strain of the genus *Pichia*.

A further object of our invention is a process for producing polypeptides employing the novel yeast strain as described hereinabove.

These and other objects of our invention will become apparent from the disclosure and claims herein provided.

#### Statement of the Invention

In accordance with the present invention, we have discovered, isolated and characterized DNA sequences which control the transcription of DNA into messenger RNA and translation of the messenger RNA to give a polypeptide product. The novel DNA sequences of this invention are useful for the production of polypeptide products by (a) yeast strains which are capable of growth on methanol as a carbon and energy source, (b) yeast strains which are capable of growth on glucose, ethanol, fructose and the like; and (c) yeast strains which are capable of growth on glycerol, galactose, acetate and the like.

#### Brief Description of the Figures

Figure 1 is a correlation of the relationship between the genomic clone (pPG 6.0) and cDNA clone (pPC 15.0) for protein p76.

Figure 2 is a correlation of the relationship between the genomic clone (pPG 4.0) and cDNA clones (pPC 8.3 and pPC 8.0) for protein p72 (alcohol oxidase).

Figure 3 is a correlation of the relationship between the genomic clone (pPG 4.8) and cDNA clone (pPC 6.7) for protein p40.

Figure 4 provides restriction maps of regulatory regions of the invention from clone pPG 6.0.

Figure 5 is a restriction map of the regulatory region of the invention from clone pPG 4.0.

Figure 6 is a restriction map of the regulatory region of the invention from clone pPG 4.8.

Figure 7 is a restriction map of a sequence of DNA obtained from the 3' end of the p76 structural gene.

Figure 8 provides restriction maps of sequences of DNA obtained from the 3' end of the p72 (alcohol oxidase) structural gene.

Figure 9 is a restriction map of a sequence of DNA obtained from the 3' end of the p40 structural gene.

Figure 10 is a restriction map of the protein p76 structural gene and the 5' regulatory region thereof.

Figure 11 is a restriction map of the protein p40 structural gene and the 5' regulatory region thereof.

Figure 12 is a restriction map of the protein p76 cDNA.

Figure 13 is a restriction map of the protein p72 (alcohol oxidase) cDNA.

Figure 14 is a restriction map of the protein p40 cDNA.

Figure 15 provides restriction maps of two novel p76 regulatory region-*lacZ* DNA constructs of the invention.

Figure 16 is a restriction map of a novel p72 (alcohol oxidase) regulatory region-*lacZ* DNA construct of the invention.

Figure 17 is a restriction map of plasmid pSAOH 1.

Figure 18 is a restriction map of plasmid pSAOH 5.

Figure 19 is a restriction map of plasmid pSAOH 10.

Figure 20 is a restriction map of plasmid pTAFH.85.

Figure 21 is a restriction map of plasmid pT76H 1.

Figure 22 is a restriction map of plasmid pT76H 2.

Figure 22a is a restriction map of plasmid pT76H3.

Figure 22b is a restriction map of plasmid pT76H4.

Figure 23 is a restriction map of plasmid pYA2.

Figure 24 is a restriction map of plasmid pYA4.

Figure 25 is a restriction map of plasmid pYJ8.

Figure 26 is a restriction map of plasmid pYJ8ΔC/a.

Figure 27 is a restriction map of plasmid pYJ30.

Figure 28 provides a restriction map of plasmid pTAFH 1 and shows how the plasmid was derived.

Figure 29 provides a restriction map of plasmid pTAO 12 and shows how the plasmid was derived.

Figure 30 is a restriction map of plasmid pTAO13.

Figure 30a is a restriction map of plasmid pT76U1.

Figure 31 provides a restriction map of plasmid pTAO1 and shows how the plasmid was derived.

5 Figure 32 provides a restriction map of plasmid pTAF.85 and shows how the plasmid was derived.

Figure 33 provides a restriction map of plasmid YEp13.

Figure 34 is a restriction map of pBPf1.

The following abbreviations are used throughout this application to represent the restriction enzymes employed:

10	A	= <i>Asu</i> II
	B	= <i>Bam</i> HI
	B <sub>2</sub>	= <i>Bgl</i> II
	Bc	= <i>Bcl</i> I
	C	= <i>Cla</i> I
15	H <sub>2</sub>	= <i>Hinc</i> II
	H <sub>3</sub>	= <i>Hind</i> III
	K	= <i>Kpn</i> I
	Nd <sub>1</sub>	= <i>Nde</i> I
	Nr	= <i>Nru</i> I
20	Ps	= <i>Pst</i> I
	Pv <sub>1</sub>	= <i>Pvu</i> I
	Pv <sub>2</sub>	= <i>Pvu</i> II
	R <sub>1</sub>	= <i>Eco</i> RI
	R <sub>5</sub>	= <i>Eco</i> RV
25	Rs	= <i>Rsa</i> I
	S	= <i>Sal</i> I
	S <sub>3</sub>	= <i>Sau</i> 3AI
	Sc	= <i>Sac</i> I
	Sm	= <i>Sma</i> I
30	Sp	= <i>Sph</i> I
	Ss	= <i>Sst</i> I
	St	= <i>Stu</i> I
	T	= <i>Taq</i> I
	Th	= <i>Tha</i> I
35	Xb	= <i>Xba</i> I
	Xh	= <i>Xho</i> I
	Xm	= <i>Xma</i> I

In the attached figures, restriction sites employed for manipulation of DNA fragments, but which are destroyed upon ligation are indicated by enclosing the abbreviation for the destroyed site in parentheses.

#### 40 Detailed Description of the Invention

In accordance with the present invention, there is provided a novel DNA fragment comprising a regulatory region responsive to at least one of the following conditions: the presence of methanol, carbon source starvation when cells are grown on some substrates other than methanol, and the presence of non-catabolite repressing carbon sources other than methanol. The regulatory region of the DNA fragment of this invention is capable of controlling the transcription of messenger RNA when positioned at the 5' end of the DNA which codes for the production of messenger RNA. Also included within the scope of our invention are mutants of the above-described DNA fragment.

50 Further in accordance with the present invention, there is provided a DNA fragment which comprises a regulatory region which is capable of controlling the polyadenylation, termination of transcription and termination of translation of messenger RNA when positioned at the 3' end of the polypeptide coding region which codes for the production of messenger RNA, wherein the transcription and translation of the messenger RNA is controlled by a regulatory region which is responsive to at least one of the following conditions: the presence of methanol, carbon source starvation when cells are grown on some substrates other than methanol and the presence of non-catabolite repressing carbon sources other than methanol. Also included within the scope of our invention are mutants of the above-described DNA fragment.

Still further in accordance with a specific embodiment of the invention, there are provided DNA

fragments which direct the incorporation of encoded polypeptide into peroxisomes. Peroxisomes are intracellular bodies present in large amounts in methanol grown yeast cells. These intracellular bodies serve to isolate the incorporated polypeptide product from intracellular fluids and enzymes such as proteases.

In accordance with another embodiment of the invention, genes coding for the production of alcohol oxidase, a protein of about 40 kilodaltons and a protein of about 76 kilodaltons are provided.

In accordance with yet another embodiment of the present invention, plasmids and transformed organisms containing the above-described DNA fragments are provided.

In accordance with still another embodiment of the invention, methods are provided for producing the plasmids and DNA fragments of the invention, as well as heterologous polypeptides, i.e., polypeptides not native to the host organisms.

#### Isolation of Regulatable Genes from *Pichia pastoris*

An approximately 20,000 member cDNA library was prepared in *E. coli* with poly A+ RNA isolated from *Pichia pastoris* cells grown on methanol as the sole carbon source (See Example III). The library was screened by hybridization using kinased poly A+ RNA isolated from *Pichia pastoris* grown either in the presence of methanol or ethanol. After several rounds of this plus-minus screening, three distinct, non-homologous cDNA clones were identified as being copies of methanol specific messenger RNA's. These clones were designated as pPC 6.4, pPC 8.0, and pPC 15.0 and were determined to contain inserts of 470, 750 and 1100 nucleotides in length, respectively.

In an attempt to obtain cDNA clones of longer length, a second cDNA library was prepared using milder S1 nuclease digestion conditions than used for the preparation of the first cDNA library and the members of this new library screened individually with <sup>32</sup>P-labeled cDNA clones pPC 6.4, pPC 8.0, and pPC 15.0. As a result, larger cDNA clones were isolated corresponding to cDNA clones pPC 6.4 and pPC 8.0. The larger clones, pPC 6.7 and pPC 8.3, were found to contain inserts measuring 1200 and 2100 nucleotides, respectively (See Figures 2 and 3). A cDNA clone possessing an insert larger than the 1100 nucleotides for pPC 15.0 has not been observed after screening more than 40,000 cDNA clones.

The isolation of the genomic DNA fragments corresponding to each of these cDNA clones was accomplished by first cutting out and electroeluting from agarose gels *Pichia pastoris* DNA fragments of restriction endonuclease treated chromosomal DNA that hybridized with <sup>32</sup>P-labeled pPC 15.0, pPC 8.0, or pPC 6.4. Then the eluted genomic DNA fragments were cloned into *Escherichia coli* and the appropriate genomic clones identified by screening several times with each of the above cDNA probes.

The relationship of each cDNA clone to its corresponding genomic clone is illustrated in Figures 1, 2, and 3. pPC 15.0 is encoded within a 6000 nucleotide *HindIII* genomic fragment present in clone pPG 6.0 (Figure 1). The 5' end of the gene encoded by pPC 15.0 is oriented toward the 1300 bp *HindIII*-*EcoRI* fragment contained in pPG 6.0, while the 3' end of the gene is proximal to the *PstI* sites in pPG 6.0.

The cDNA clone pPC 8.3 is included within the genomic clone pPG 4.0 (Figure 2). pPG 4.0 contains an *EcoRI*-*PvuII* insert of 4000 nucleotides of contiguous genomic DNA. The orientation of pPC 8.3 within pPG 4.0 places the 5' end of the gene for this cDNA clone close to the *BamHI* sites while the 3' end of this gene is located near the *PvuII* site. The orientation of pPC 8.0 (a related cDNA clone) within pPG 4.0 places the 5' end of this cDNA clone close to the *KpnI* site at the 3' end of pPG 4.0 and the 3' end of the cDNA clone is located near the *PvuII* site.

The cDNA clone pPC 6.7 is located entirely within a 4800 nucleotide *EcoRI*-*BamHI* genomic fragment (Figure 3). Clone pPC 6.4 is in turn located completely within cDNA clone pPC 6.7. Since pPC 6.7 was a more complete copy than pPC 6.4, the latter was not investigated further. The 5' end of the gene is positioned closer to the *BamHI* end than to the *EcoRI* end of the genomic clone pPG 4.8 (Figure 3).

In all of these above-described genomic clones, there are at least 1.2 kilobase pairs of flanking genomic DNA sequence which are 5' to the structural genes copied in each of the cDNA clones.

Each of the genomic and cDNA clones described above have been deposited with the Northern Regional Research Center of the United States of America, Peoria, Illinois.

All clones have been deposited in *E. coli* hosts:

Plasmid	Host	Accession No.
pPG 6.0	<i>E. coli</i> LE392-pPG 6.0	NRRL B-15867
pPG 4.0	<i>E. coli</i> LE392-pPG 4.0	NRRL B-15868
pPG 4.8	<i>E. coli</i> LE392-pPG 4.8	NRRL B-15869
pPC 15.0	<i>E. coli</i> LE392-pPC 15.0	NRRL B-15870
pPC 8.3	<i>E. coli</i> LE392-pPC 8.3	NRRL B-15871
pPC 6.7	<i>E. coli</i> LE392-pPC 6.7	NRRL B-15872
pPC 8.0	<i>E. coli</i> MM294-pPC 8.0	NRRL B-15873

All of the above organisms have been irrevocably deposited and made available to the public as of August 31, 1984.

#### Uniqueness of pPG 6.0, pPG 4.0 and pPG 4.8 to Methanol Assimilating Yeasts

Each of the cDNA clones described above have been labeled and employed as probes of chromosomal DNA sequences from a number of methanol assimilating yeasts and a methanol non-assimilating yeast. Homologous genes for all three of the cDNAs were found to exist in essentially all methanol assimilating yeasts, but were clearly not present in methanol non-assimilating yeast (*S. cerevisiae*). It is thus believed that these genes are unique to methanol assimilating yeast. In addition, the southern hybridization experiments detailed in Example XVII demonstrate that a high degree of homology exists between these unique methanol responsive genes from various methanol assimilating yeasts.

#### Characterization of the RNA Transcripts of the pPG 6.0, pPG 4.0 and pPG 4.8 Genes

The influence of methanol on the expression of each of these cloned genes can be observed by studying the effects on transcription of these genes. Isolated poly A+ RNA from *Pichia pastoris* cells grown with ethanol or methanol as sole carbon source was used to prepare Northern hybridization filters (See Example IV). Three identical pairs of filters from methanol and ethanol grown cells (See Example I) were probed separately with <sup>32</sup>P-labeled pPC 15.0, pPC 8.0 and pPC 6.4. The clones pPC 15.0, pPC 8.0, and pPC 6.4 hybridized to RNA molecules (of approximately 2400, 2300, and 1300 nucleotides, respectively) from methanol grown cells. No hybridization of clones pPC 15.0 and pPC 8.0 with the hybridization probes was observed with RNA obtained from cells grown in the presence of ethanol. However, when RNA isolated from cells grown on ethanol was probed with pPC 6.4, the clone hybridized to a 1300-nucleotide RNA molecule identical to that seen with methanol-grown cells but at an estimated (qualitatively) 5-fold lower level.

#### Size Determination of Protein Products Encoded by pPG 6.0, pPG 4.0 and pPG 4.8

To determine what protein products were encoded by each of the above-identified cDNA clones, poly A+ RNA from *Pichia pastoris* cells grown on methanol was selectively hybridized to each of the cDNA clones. The hybrid-selected mRNA, i.e., mRNA which hybridized to each of the cDNA clones, was then translated *in vitro* and each of the protein products resolved by electrophoresis using SDS-denaturing conditions (See Example V). The results of these *in vitro* positive hybridization-translation experiments indicated that clones pPC 15.0, pPC 8.3, and pPC 6.7 select mRNAs which encode information for polypeptides of 76,000 (p76), 72,000 (p72) and 40,000 (p40) daltons, respectively. These same proteins are observed when total poly A+ RNA (i.e., not hybrid-selected) from methanol grown *Pichia pastoris* cells is translated in the same *in vitro* system.

#### Identification of p72 as Alcohol Oxidase

##### A. Molecular Weight Comparison

A sample highly enriched for alcohol oxidase protein was prepared by dialysis of cleared cell lysates against H<sub>2</sub>O (See Example VII). The crystalline precipitate resulting from this dialysis was shown by SDS electrophoresis to contain predominantly two polypeptides of 76,000 and 72,000 daltons, respectively. The precipitate was subjected to additional purification by chromatography through Sephacryl 200 (See Example VII), which demonstrated that alcohol oxidase activity corresponded to the activity of the purified 72,000



dalton polypeptide. The size of this polypeptide was identical to that of the protein product selected by cDNA clone pPC 8.3 (See Example X).

#### B. Immunoprecipitation

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Additional support that clones pPC 8.3 and pPG 4.0 encode the alcohol oxidase structural gene was obtained by means of an immunological approach (Example XI). The protein preparation isolated from *Pichia pastoris* containing both the 76,000 and 72,000 dalton polypeptides was used to raise specific antisera for these polypeptides in rabbits. When the hybrid-selected poly A+ RNA from clone pPC 8.3 was translated *in vitro*, only the 72,000 dalton translation product was precipitated by the antisera made against the protein preparation from *Pichia pastoris* cells.

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#### C. Predicted/Actual Amino Acid Sequence Comparison

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To further verify that clone pPC 8.3 is in fact the cDNA clone encoding *Pichia pastoris* alcohol oxidase, the amino acid sequence for the amino terminal end of the protein was compared with the predicted amino acid sequence encoded by pPC 8.3. Thus, the NH<sub>2</sub>-terminal amino acid sequence (Sequence A) of the isolated 72,000 dalton protein was determined (Example VIII) to be:

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Ala-Ile-Pro-Glu-Glu-Phe-Asp-Ile-Leu-Val-Leu-Gly-Gly-Gly-Ser-Ser-Gly-Ser.

#### Sequence A

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In parallel, the nucleotide sequence of the 5' end of the gene encoded in pPC 8.3 and pPG 4.0 was determined. The predicted amino acid sequence for amino acids 2-19 (See Sequence B) derived from the DNA sequences of both the genomic and cDNA clones agreed perfectly with the first 18 amino acids of the above determined amino acid sequence (Sequence A) for isolated *Pichia pastoris* alcohol oxidase:

30

#### Predicted amino acid

35

sequence: Met ala ile pro glu glu phe

Nucleotide sequence 5'-ATG GCT ATC CCC GAA GAG TTT  
(pPC 8.3 and pPG 4.0): 3'-TAC CGA TAG GGG CTT CTC AAA

40

asp ile leu val leu gly gly gly ser ser gly ser  
GAT ATC CTA GTT CTA GGT GGT GGA TCC AGT GGA TCC-3'  
CTA TAG GAT CAA GAT CCA CCA CCT AGG TCA CCT AGG-5'

45

#### Sequence B

In addition, the entire nucleotide sequence for the coding region of the alcohol oxidase gene was determined. The nucleotide sequence determined and the predicted amino acid sequence are set forth in Sequence B' and are believed to be:

50

55

## Predicted amino acid

sequence:

Met ala ile pro glu glu phe

6

Nucleotide sequence 5'-ATG GCT ATC CCC GAA GAG TTT  
 (pPC 8.3 and pPG 4.0):3'-TAC CGA TAG GGG CTT CTC AAA

10

asp ile leu val leu gly gly gly ser ser gly ser  
 GAT ATC CTA GTT CTA GGT GGT GGA TTC AGT GGA TCC  
 CTA TAG GAT CAA GAT CCA CCA CCT AGG TCA CCT AGG

15

cys ile ser gly arg leu ala asn leu asp his ser  
 TGT ATT TCC GGA AGA TTG GCA AAC TTG GAC CAC TCC  
 ACA TAA AGG CCT TCT AAC CGT TTG AAC CTG GTG AGG

20

leu lys val gly leu ile glu ala gly glu asn gln  
 TTG AAA GTT GGT CTT ATC GAA GCA GGT GAG AAC CAA  
 AAC TTT CAA CCA GAA TAG CTT CGT CCA CTC TTG GTT

25

pro gln gln pro met gly leu pro ser arg tyr leu  
 CCT CAA CAA CCC ATG GGT CTA CCT TCC AGG TAT TTA  
 GGA GTT GTT GGG TAC CCA GAT GGA AGG TCC ATA AAT

30

pro lys lys gln lys leu asp ser lys thr ala ser  
 CCC AAG AAA CAG AAG TTG GAC TCC AAG ACT GCT TCC  
 GGG TTC TTT GTC TTC AAC CTG AGG TTC TGA CGA AGG

35

phe tyr thr ser asn pro ser pro his leu asn gly  
 TTC TAC ACT TCT AAC CCA TCT CCT CAC TTG AAT GGT  
 AAG ATG TGA AGA TTG GGT AGA GGA GTG AAC TTA CCA

40

arg arg ala ile val pro cys ala asn val leu gly  
 AGA AGA GCC ATC GTT CCA TGT GCT AAC GTC TTG GGT  
 TCT TCT CGG TAG CAA GGT ACA CGA TTG CAG AAC CCA

45

gly gly ser ser ile asn phe met met tyr thr arg  
 GGT GGT TCT TCT ATC AAC TTC ATG ATG TAC ACC AGA  
 CCA CCA AGA AGA TAG TTG AAG TAC TAC ATG TGG TCT

gly ser ala ser asp ser asp asp ? gln ala glu  
 GGT TCT GCT TCT GAT TCT GAT GAC TTN CAA GCC GAG  
 CCA AGA CGA AGA CTA AGA CTA CTG AAN GTT CGG CTC

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gly ser lys thr glu asp leu leu pro leu met lys  
 GGC TCG AAA ACA GAG GAC TTG CTT CCA TTG ATG AAA  
 CCG AGC TTT TGT CTC CTG AAC GAA GGT AAC TAC TTT

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	<i>lys</i>	<i>thr</i>	<i>glu</i>	<i>thr</i>	<i>tyr</i>	<i>gln</i>	<i>arg</i>	<i>ala</i>	<i>?</i>	<i>gln</i>	<i>?</i>	<i>tyr</i>
	AAG	ACT	GAG	ACC	TAC	CAA	AGA	GCT	TGN	CAA	CNA	TAC
5	TTC	TGA	CTC	TGG	ATG	GTT	TCT	CGA	ACN	GTT	GNT	ATG
	<i>pro</i>	<i>asp</i>	<i>ile</i>	<i>his</i>	<i>gly</i>	<i>phe</i>	<i>glu</i>	<i>gly</i>	<i>pro</i>	<i>ile</i>	<i>lys</i>	<i>val</i>
	CCT	GAC	ATT	CAC	GGT	TTC	GAA	GGT	CCA	ATC	AAG	GTT
	GGA	CTG	TAA	GTG	CCA	AAG	CTT	CCA	GGT	TAG	TTC	CAA
10	<i>ser</i>	<i>phe</i>	<i>gly</i>	<i>asn</i>	<i>tyr</i>	<i>thr</i>	<i>tyr</i>	<i>pro</i>	<i>val</i>	<i>cys</i>	<i>gln</i>	<i>asp</i>
	TCT	TTC	GGT	AAC	TAC	ACC	TAC	CCA	GTT	TGC	CAG	GAC
	AGA	AAG	CCA	TTG	ATG	TGG	ATG	GGT	CAA	ACG	GTC	CTG
	<i>phe</i>	<i>leu</i>	<i>arg</i>	<i>ala</i>	<i>ser</i>	<i>glu</i>	<i>ser</i>	<i>gln</i>	<i>gly</i>	<i>ile</i>	<i>pro</i>	<i>tyr</i>
	TTC	TTG	AGG	GCT	TCT	GAG	TCC	CAA	GGT	ATT	CCA	TAC
15	AAG	AAC	TCC	CGA	AGA	CTC	AGG	GTT	CCA	TAA	CGT	ATG
	<i>val</i>	<i>asp</i>	<i>asp</i>	<i>leu</i>	<i>glu</i>	<i>asp</i>	<i>leu</i>	<i>val</i>	<i>leu</i>	<i>thr</i>	<i>his</i>	<i>gly</i>
	GTT	GAC	GAT	CTG	GAA	GAC	TTG	GTA	CTG	ACT	CAC	GGT
	CAA	CTG	CTA	GAC	CTT	CTG	AAC	CAT	GAC	TGA	GTG	CCA
20	<i>ala</i>	<i>glu</i>	<i>his</i>	<i>trp</i>	<i>leu</i>	<i>lys</i>	<i>trp</i>	<i>ile</i>	<i>asn</i>	<i>arg</i>	<i>asp</i>	<i>thr</i>
	GCT	GAA	CAC	TGG	TTG	AAG	TGG	ATC	AAC	AGA	GAC	ACT
	CGA	CTT	GTG	ACC	AAC	TTC	ACC	TAG	TTG	TCT	CTG	TGA
	<i>gly</i>	<i>arg</i>	<i>arg</i>	<i>ser</i>	<i>asp</i>	<i>ser</i>	<i>ala</i>	<i>his</i>	<i>ala</i>	<i>phe</i>	<i>val</i>	<i>his</i>
25	CGT	CGT	TCC	GAC	TCT	GCT	CAT	GCA	TTT	GTC	CAC	TCT
	GCA	GCA	AGG	CTG	AGA	CGA	GTA	CGT	AAA	CAG	GTG	AGA
	<i>ser</i>	<i>thr</i>	<i>met</i>	<i>arg</i>	<i>asn</i>	<i>his</i>	<i>asp</i>	<i>asn</i>	<i>leu</i>	<i>tyr</i>	<i>leu</i>	<i>ile</i>
	TCT	ACT	ATG	AGA	AAC	CAC	GAC	AAC	TTG	TAC	TTG	ATC
30	AGA	TGA	TAC	TCT	TTG	GTG	CTG	TTG	AAC	ATG	AAC	TAG
	<i>cys</i>	<i>asn</i>	<i>thr</i>	<i>lys</i>	<i>val</i>	<i>asp</i>	<i>lys</i>	<i>ile</i>	<i>ile</i>	<i>val</i>	<i>glu</i>	<i>asp</i>
	TGT	AAC	ACG	AAG	GTC	GAC	AAA	ATT	ATT	GTC	GAA	GAC
	ACA	TTG	TGC	TTC	CAG	CTG	TTT	TAA	TAA	CAG	CTT	CTG
35	<i>gly</i>	<i>arg</i>	<i>ala</i>	<i>ala</i>	<i>ala</i>	<i>val</i>	<i>arg</i>	<i>thr</i>	<i>val</i>	<i>pro</i>	<i>ser</i>	<i>lys</i>
	GGA	AGA	GCT	GCT	GCT	GTT	AGA	ACC	GTT	CCA	AGC	AAG
	CCT	TCT	CGA	CGA	CGA	CAA	TCT	TGG	CAA	GGT	TCG	TTC
	<i>pro</i>	<i>leu</i>	<i>asn</i>	<i>pro</i>	<i>lys</i>	<i>lys</i>	<i>pro</i>	<i>ser</i>	<i>his</i>	<i>lys</i>	<i>ile</i>	<i>tyr</i>
40	CCT	TTG	AAC	CCA	AAG	AAG	CCA	AGT	CAC	AAG	ATC	TAC
	GCA	AAC	TTG	GGT	TTC	TTC	GGT	TCA	GTG	TTC	TAG	ATG
	<i>arg</i>	<i>ala</i>	<i>arg</i>	<i>lys</i>	<i>gln</i>	<i>ile</i>	<i>phe</i>	<i>leu</i>	<i>ser</i>	<i>cys</i>	<i>gly</i>	<i>thr</i>
	CGT	GCT	AGA	AAG	CAA	ATC	TTT	TTG	TCT	TGT	GGT	ACC
45	GCA	CGA	TCT	TTC	GTT	TAG	AAA	AAC	AGA	ACA	CCA	TGG
	<i>ile</i>	<i>ser</i>	<i>ser</i>	<i>pro</i>	<i>leu</i>	<i>val</i>	<i>leu</i>	<i>gln</i>	<i>arg</i>	<i>ser</i>	<i>gly</i>	<i>phe</i>
	ATC	TCC	TCT	CCA	TTG	GTT	TTG	CAA	AGA	TCC	GGT	TTT
	TAG	AGG	AGA	GGT	AAC	CAA	AAC	GTT	TCT	AGG	CCA	AAA

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	<i>gly</i>	<i>asp</i>	<i>pro</i>	<i>ile</i>	<i>lys</i>	<i>leu</i>	<i>arg</i>	<i>ala</i>	<i>ala</i>	<i>gly</i>	<i>val</i>	<i>lys</i>
	GGT	GAC	CCA	ATC	AAG	TTG	AGA	GCC	GCT	GGT	GTT	AAG
	CCA	CTG	GGT	TAG	TTC	AAC	TCT	CGG	CGA	CCA	CAA	TTC
5	<i>pro</i>	<i>leu</i>	<i>val</i>	<i>asn</i>	<i>leu</i>	<i>pro</i>	<i>gly</i>	<i>val</i>	<i>gly</i>	<i>arg</i>	<i>asn</i>	<i>phe</i>
	CCT	TTG	GTC	AAC	TTG	CCA	GGT	GTC	GGA	AGA	AAC	TTC
	GGA	AAC	CAG	TTG	AAC	GGT	CCA	CAG	CCT	TCT	TTG	AAG
	<i>gln</i>	<i>asp</i>	<i>his</i>	<i>tyr</i>	<i>cys</i>	<i>phe</i>	<i>phe</i>	<i>ser</i>	<i>pro</i>	<i>tyr</i>	<i>arg</i>	<i>ile</i>
10	CAA	GAC	CAT	TAT	TGT	TTC	TTC	AGT	CCT	TAC	AGA	ATC
	GTT	CTG	GTA	ATA	ACA	AAG	AAG	TCA	GGA	ATG	TCT	TAG
	<i>lys</i>	<i>pro</i>	<i>gln</i>	<i>tyr</i>	<i>glu</i>	<i>ser</i>	<i>phe</i>	<i>asp</i>	<i>asp</i>	<i>phe</i>	<i>val</i>	<i>arg</i>
	AAG	CCT	CAG	TAC	GAG	TCT	TTC	GAT	GAC	TTC	GTC	CGT
15	TTC	GCA	GTC	ATG	CTC	AGA	AAG	CTA	CTG	AAG	CAG	GCA
	<i>gly</i>	<i>asp</i>	<i>ala</i>	<i>glu</i>	<i>ile</i>	<i>gln</i>	<i>lys</i>	<i>arg</i>	<i>val</i>	<i>val</i>	<i>asp</i>	<i>gln</i>
	GGT	GAT	GCT	GAG	ATT	CAA	AAG	AGA	GTC	GTT	GAC	CAA
	CCA	CTA	CGA	CTC	TAA	GTT	TTC	TCT	CAG	CAA	CTG	GTT
20	<i>trp</i>	<i>tyr</i>	<i>ala</i>	<i>asn</i>	<i>gly</i>	<i>thr</i>	<i>gly</i>	<i>pro</i>	<i>leu</i>	<i>ala</i>	<i>thr</i>	<i>asn</i>
	TGG	TAC	GCC	AAT	GGT	ACT	GGT	CCT	CTT	GCC	ACT	AAC
	ACC	ATG	CGG	TTA	CCA	TGA	CCA	GGA	GAA	CGG	TGA	TTG
	<i>gly</i>	<i>ile</i>	<i>glu</i>	<i>ala</i>	<i>gly</i>	<i>val</i>	<i>lys</i>	<i>ile</i>	<i>arg</i>	<i>pro</i>	<i>thr</i>	<i>pro</i>
25	GGT	ATC	GAA	GCT	GGT	GTC	AAG	ATC	AGA	CCA	ACA	CCA
	CCA	TAG	CTT	CGA	CCA	CAG	TTC	TAG	TCT	GGT	TGT	GGT
	<i>glu</i>	<i>glu</i>	<i>leu</i>	<i>ser</i>	<i>gln</i>	<i>met</i>	<i>asp</i>	<i>glu</i>	<i>ser</i>	<i>phe</i>	<i>gln</i>	<i>glu</i>
	GAA	GAA	CTC	TCT	CAA	ATG	GAC	GAA	TCC	TTC	CAG	GAG
	CTT	CTT	GAG	AGA	GTT	TAC	CTG	CTT	AGG	AAG	GTC	CTC
30	<i>gly</i>	<i>tyr</i>	<i>arg</i>	<i>glu</i>	<i>tyr</i>	<i>phe</i>	<i>glu</i>	<i>asp</i>	<i>lys</i>	<i>pro</i>	<i>asp</i>	<i>lys</i>
	GGT	TAC	AGA	GAA	TAC	TTC	GAA	GAC	AAG	CCA	GAC	AAG
	CCA	ATG	TCT	CTT	ATG	AAG	CTT	CTG	TTC	GGT	CTG	TTC
	<i>pro</i>	<i>val</i>	<i>met</i>	<i>his</i>	<i>tyr</i>	<i>ser</i>	<i>ile</i>	<i>ile</i>	<i>ala</i>	<i>gly</i>	<i>phe</i>	<i>phe</i>
35	CCA	GTT	ATG	CAC	TAC	TCC	ATC	ATT	GCT	GGT	TTC	TTC
	GGT	CAA	TAC	GTG	ATG	AGG	TAG	TAA	CGA	CCA	AAG	AAG
	<i>gly</i>	<i>asp</i>	<i>his</i>	<i>thr</i>	<i>lys</i>	<i>ile</i>	<i>pro</i>	<i>pro</i>	<i>gly</i>	<i>lys</i>	<i>tyr</i>	<i>met</i>
	GGT	GAC	CAC	ACC	AAG	ATT	CCT	CCT	GGA	AAG	TAC	ATG
40	CCA	CTG	GTG	TGG	TTC	TAA	GGA	GGA	CCT	TTC	ATG	TAC
	<i>thr</i>	<i>met</i>	<i>phe</i>	<i>his</i>	<i>phe</i>	<i>leu</i>	<i>glu</i>	<i>tyr</i>	<i>pro</i>	<i>phe</i>	<i>ser</i>	<i>arg</i>
	ACT	ATG	TTC	CAC	TTC	TTG	GAA	TAC	CCA	TTC	TCC	AGA
	TGA	TAC	AAG	GTG	AAG	AAC	CTT	ATG	GGT	AAG	AGG	TCT
45	<i>gly</i>	<i>ser</i>	<i>ile</i>	<i>his</i>	<i>ile</i>	<i>thr</i>	<i>ser</i>	<i>pro</i>	<i>asp</i>	<i>pro</i>	<i>tyr</i>	<i>ala</i>
	GGT	TCC	ATT	CAC	ATT	ACC	TCC	CCA	GAC	CCA	TAC	GCA
	CCA	AGG	TAA	GTG	TAA	TGG	AGG	GGT	CTG	GGT	ATG	CGT

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	<i>ala</i>	<i>pro</i>	<i>asp</i>	<i>phe</i>	<i>asp</i>	<i>arg</i>	<i>gly</i>	<i>phe</i>	<i>met</i>	<i>asn</i>	<i>asp</i>	<i>glu</i>
	GCT	CCA	GAC	TTC	GAC	CGA	GGT	TTC	ATG	AAC	GAT	GAA
	CGA	GGT	CTG	AAG	CTG	GCT	CCA	AAG	TAC	TTG	CTA	CTT
5	<i>arg</i>	<i>asp</i>	<i>met</i>	<i>ala</i>	<i>pro</i>	<i>met</i>	<i>val</i>	<i>trp</i>	<i>ala</i>	<i>tyr</i>	<i>lys</i>	<i>ser</i>
	AGA	GAC	ATG	GCT	CCT	ATG	GTT	TGG	GCT	TAC	AAG	TCT
	TCT	CTG	TAC	CGA	GGA	TAC	CAA	ACC	CGA	ATG	TTC	TTC
	<i>ser</i>	<i>arg</i>	<i>glu</i>	<i>thr</i>	<i>ala</i>	<i>arg</i>	<i>arg</i>	<i>ser</i>	<i>asp</i>	<i>his</i>	<i>phe</i>	<i>ala</i>
10	TCT	AGA	GAA	ACC	GCT	AGA	AGA	AGT	GAC	CAC	TTT	GCC
	AGA	TCT	CTT	TGG	CGA	TCT	TCT	TCA	CTG	GTG	AAA	CGG
	<i>gly</i>	<i>glu</i>	<i>val</i>	<i>thr</i>	<i>ser</i>	<i>his</i>	<i>his</i>	<i>pro</i>	<i>leu</i>	<i>phe</i>	<i>pro</i>	<i>tyr</i>
	GGT	GAG	GTC	ACT	TCT	CAC	CAC	CCT	CTG	TTC	CCA	TAC
15	CCA	CTC	CAG	TGA	AGA	GTG	GTG	GGA	GAC	AAG	GGT	ATG
	<i>ser</i>	<i>ser</i>	<i>glu</i>	<i>ala</i>	<i>arg</i>	<i>ala</i>	<i>leu</i>	<i>glu</i>	<i>met</i>	<i>asp</i>	<i>leu</i>	<i>glu</i>
	TCA	TCC	GAG	GCC	AGA	GCC	TTG	GAA	ATG	GAT	TTG	GAG
	AGT	AGG	CTC	CGG	TCT	CGG	AAC	CTT	TAC	CTA	AAC	CTC
20	<i>thr</i>	<i>ser</i>	<i>asn</i>	<i>ala</i>	<i>tyr</i>	<i>gly</i>	<i>gly</i>	<i>pro</i>	<i>leu</i>	<i>asn</i>	<i>leu</i>	<i>ser</i>
	ACC	TCT	AAT	GCC	TAC	GGT	GGA	CCT	TTG	AAC	TTG	TCT
	TGG	AGA	TTA	CGG	ATG	CCA	CCT	GGA	AAC	TTG	AAC	AGA
	<i>ala</i>	<i>gly</i>	<i>leu</i>	<i>ala</i>	<i>his</i>	<i>gly</i>	<i>ser</i>	<i>trp</i>	<i>thr</i>	<i>gln</i>	<i>pro</i>	<i>leu</i>
25	GCT	GGT	CTT	GCT	CAC	GGT	TCT	TGG	ACT	CAA	CCT	TTG
	CGA	CCA	GAA	CGA	GTG	CCA	AGA	ACC	TGA	GTT	GGA	AAC
	<i>lys</i>	<i>lys</i>	<i>pro</i>	<i>thr</i>	<i>ala</i>	<i>lys</i>	<i>asn</i>	<i>glu</i>	<i>gly</i>	<i>his</i>	<i>val</i>	<i>thr</i>
	AAG	AAG	CCA	ACT	GCA	AAG	AAC	GAA	GGC	CAC	GIT	ACT
30	TTC	TTC	GGT	TGA	CGT	TTC	TTG	CTT	CCG	GTG	CAA	TGA
	<i>ser</i>	<i>asn</i>	<i>gln</i>	<i>val</i>	<i>glu</i>	<i>leu</i>	<i>his</i>	<i>pro</i>	<i>asp</i>	<i>ile</i>	<i>glu</i>	<i>tyr</i>
	TCG	AAC	CAG	GTC	GAG	CTT	CAT	CCA	GAC	ATC	GAG	TAC
	AGC	TTG	GTC	CAG	CTC	GAA	GTA	GGT	CTG	TAG	CTC	ATG
35	<i>asp</i>	<i>glu</i>	<i>glu</i>	<i>asp</i>	<i>asp</i>	<i>lys</i>	<i>ala</i>	<i>ile</i>	<i>glu</i>	<i>asn</i>	<i>tyr</i>	<i>ile</i>
	GAT	GAG	GAG	GAT	GAC	AAG	GCC	ATT	GAG	ACC	TAC	ATT
	CTA	CTC	CTC	CTA	CTG	TTC	CGG	TAA	CTC	TTG	ATG	TAA
	<i>arg</i>	<i>glu</i>	<i>his</i>	<i>thr</i>	<i>glu</i>	<i>thr</i>	<i>thr</i>	<i>trp</i>	<i>his</i>	<i>cys</i>	<i>leu</i>	<i>gly</i>
40	CGT	GAG	CAC	ACT	GAG	ACC	ACA	TGG	CAC	TGT	CTG	GGA
	GCA	CTC	GTG	TGA	CTC	TGG	TGT	ACC	GTG	ACA	CCA	GGT
	<i>thr</i>	<i>cys</i>	<i>ser</i>	<i>ile</i>	<i>gly</i>	<i>pro</i>	<i>arg</i>	<i>glu</i>	<i>gly</i>	<i>ser</i>	<i>lys</i>	<i>ile</i>
	ACC	TGT	TCC	ATC	GGT	CCA	AGA	GAA	GGT	TCC	AAG	ATC
	TGG	ACA	AGG	TAG	CCA	GGT	TCT	CTT	CCA	AGG	TTC	TAG
45	<i>val</i>	<i>lys</i>	<i>trp</i>	<i>gly</i>	<i>gly</i>	<i>val</i>	<i>leu</i>	<i>asp</i>	<i>his</i>	<i>arg</i>	<i>ser</i>	<i>asn</i>
	GTC	AAA	TGG	GGT	GGT	GTT	TIG	GAC	CAC	AGA	TCC	AAC
	CAG	TTT	ACC	CCA	CCA	CAA	AAC	CTG	GTG	TCT	AGG	TTG

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    val  tyr  gly  val  lys  gly  leu  lys  val  gly  asp  leu
GTT  TAC  GGA  GTC  AAG  GGC  TIG  AAG  GTT  GGT  GAC  TTG
CAA  ATG  CCT  CAG  TTC  CCG  AAC  TTC  CAA  CCA  CTG  AAC
5    ser  val  cys  pro  asp  asn  val  gly  cys  asn  thr  tyr
TCC  GTG  TGC  CCA  GAC  AAT  GTT  GGT  TGT  AAC  ACC  TAC
AGG  CAC  ACG  GGT  CTG  TTA  CAA  CCA  ACA  TTG  TGG  ATG
10   thr  thr  ala  leu  leu  ile  gly  glu  lys  thr  ala  thr
ACC  ACC  GCT  CTT  TTG  ATC  GGT  GAA  AAG  ACT  GCC  ACT
TGG  TGG  CGA  GAA  AAC  TAG  CCA  CTT  TTC  TGA  CGG  TGA
15   leu  val  gly  glu  asp  leu  gly  tyr  ser  gly  glu  ala
TTG  GTT  GGA  GAA  CAT  TTA  GGA  TAC  TCT  GGT  GAG  GCC
AAC  CAA  CCT  CTT  CTA  AAT  CCT  ATG  AGA  CCA  CTC  CGG
20   leu  asp  met  thr  val  pro  gln  phe  lys  leu  gly  thr
TTA  GAC  ATG  ACT  GTT  CCT  CAG  TTC  AAG  TTG  GGC  ACT
AAT  CTG  TAC  TGA  CAA  GGA  GTC  AAG  TTC  AAC  CCG  TGA
    tyr  glu  lys  thr  gly  leu  ala  arg  phe  stop
TAC  GAG  AAG  ACC  GGT  CTT  GCT  AGA  TTC  TAA-3'
25  ATG  CTC  TTC  TGG  CCA  GAA  CGA  TCT  AAG  ATT-5'

```

Sequence B'

30 A comparison of the above nucleotide sequence with the published (Ledeboer et al.) nucleotide sequence for the previously described alcohol oxidase from *Hansenula polymorpha* reveals numerous significant differences, including the predicted amino acid sequence, the actual size of the gene (and the resulting protein), codon usage bias, and the like.

Identification of p76 as Dihydroxyacetone Synthase

35 The nucleotide sequence for the first 51 nucleotides of the p76 gene was determined by standard techniques. From this sequence, the amino acid sequence for the amino terminal end of the p76 protein can be predicted:

```

40   Amino acid sequence:    met  ala  arg  ile  pro  lys
    Nucleotide sequence:  5'-ATG  GCT  AGA  ATT  CCA  AAA
                        3'-TAC  CGA  TCT  TAA  GGT  TTT
45   pro  val  ser  thr  gln  asp  asp  ile  his  gly  leu
    CCA  GTA  TCG  ACA  CAA  GAT  GAC  ATT  CAT  GAA  TTG-3'
    GGT  CAT  AGC  TGT  GTT  CTA  CTG  TAA  GTA  CTT  AAC-5'

```

50 This predicted amino acid sequence for p76 can be compared with the published amino acid sequence for the dihydroxyacetone synthase (DHAS) protein from *Hansenula polymorpha* (Manowicz et al.). Although several differences in the sequences are apparent, there are similarities between the two proteins which can be discerned:

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*Pichia* DHAS: met-ala- arg-ile-pro-lys-pro-  
*Hansenula* DHAS: met-ser-met-arg-ile-pro-lys-ala-  
 val-ser-thr-gln-asp-asp-ile-his-glu- -leu-  
 ala-ser-val-asn-asp-glu-gln-his-gln-arg-ile-

Based on the significant degree of homology and the similar protein size (about 76,000 daltons) of *Pichia* p76 and *Hansenula* DHAS, p76 has been tentatively identified as DHAS from *Pichia*.

As above with the alcohol oxidase gene, a comparison of the nucleotide sequence for the first 51 nucleotides of the *Pichia* DHAS protein with the previously published (Janowicz et al.) nucleotide sequence of *Hansenula* DHAS suggests numerous differences in codon usage bias, the predicted amino acid sequence, the total size of the gene, etc.

#### DNA Fragments Containing Regulatable Promoters from *Pichia*

##### *pastoris*

The 5' regulatory regions of the invention are detailed in restriction maps presented in Figures 4, 5 and 6. The 5' regulatory region which controls the expression of polypeptide p76 is located within the DNA fragment depicted in Figure 4a. The approximately 2.9 kilobase pair *HindIII-XhoI* fragment has been clearly demonstrated to contain the regulatory function as detailed more fully below. Since cDNA clone pPC 15.0 is not a full copy cDNA, it is most likely that at least a portion of the DNA fragment depicted in Figure 4a includes structural coding sequences for polypeptide p76. Thus, the regulatory function is believed to reside in the approximately 1300 base pair *HindIII-EcoRI* fragment shown in Figure 4b. Novel  $\beta$ -galactosidase gene containing constructs, to be discussed in greater detail below, support this suggestion.

The 5' regulatory region which controls the expression of polypeptide p72 (alcohol oxidase) is located within the approximately 2000 base pair *EcoRI-EcoRV* DNA fragment illustrated in Figure 5. Novel  $\beta$ -galactosidase gene containing constructs discussed below demonstrate the regulatable nature of this DNA fragment.

Figure 6 provides a restriction map for the approximately 3 kilobase pair *BamHI-SalI* DNA fragment which includes the 5' regulatory region which controls the production of polypeptide p40. This fragment is clearly distinguishable from the 5' regulatory regions detailed in Figures 4 and 5 based, *inter alia*, on the different restriction sites located within the DNA fragment.

Figures 10, 2a and 11 provide restriction enzyme data for the regulatory regions plus structural genes for polypeptides p76, p72(alcohol oxidase) and p40, respectively. Hence, Figure 10 provides detail for the 3.8 kilobase pair *HindIII-PstI* fragment of *Pichia pastoris* genomic DNA which controls and codes for the production of polypeptide p76. Figure 2a deals with the 4.0 kilobase pair *EcoRI-PvuII* fragment of *Pichia pastoris* genomic DNA which controls and codes for the production of polypeptide p72(alcohol oxidase). Figure 11 presents the 3.7 kilobase pair *BamHI-EcoRV* fragment of *Pichia pastoris* genomic DNA which controls and codes for the production of polypeptide p40.

The genomic clones, pPG 6.0, pPG 4.0 and pPG 4.8 have also been characterized by restriction mapping. Thus, clone pPG 6.0 is detailed in Figure 1a. As a point of reference the 5' end of the DNA fragment is deemed the origin. Clone pPG 6.0 is a *HindIII* fragment of *Pichia pastoris* chromosomal DNA which is about 6 kilobase pairs in length, and is cleaved as follows by various restriction enzymes:

Restriction Enzyme	Cleavage Sites	Distance From Origin (bp)
<i>HincII</i>	5	1070, 1740, 1890, 3320, 5520
<i>EcoRI</i>	2	1300, 3450
<i>XhoI</i>	1	2860,
<i>PstI</i>	2	3820, 4200
<i>PvuII</i>	1	4120
<i>PvuI</i>	1	4950

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Clone pPG 4.0 is illustrated in detail in Figur 2a. The clone is an *EcoRI-HindIII* fragment of chromosomal DNA which is about 4 kilobase pairs in length. Referring to the 5' end of the clone as the origin, the following restriction data was obtained for pPG 4.0:

Restriction Enzyme	Cleavage Sites	Distance From Origin (bp)
<i>HindIII</i>	3	400, 600, 1840
<i>PstI</i>	1	850
<i>BamHI</i>	2	1960, 1970
<i>SaI</i>	1	2620
<i>BglII</i>	2	1040, 2700
<i>KpnI</i>	2	500, 2730
<i>XbaI</i>	1	3330
<i>StuI</i>	1	3880
<i>NdeI</i>	1	420
<i>HincII</i>	2	870; 2430
<i>SstI</i>	1	1200
<i>BclI</i>	2	1710, 4080
<i>AsuII</i>	2	1900, 2300
<i>EcoRV</i>	1	1930
<i>PvuII</i>	1	4120

Clone pPG 4.8 is illustrated in detail in Figure 3a. The clone is a 4.8 kilobase pair *BamHI-EcoRI* fragment of *Pichia pastoris* chromosomal DNA with the following additional restriction sites:

Restriction Enzyme	Cleavage Sites	Distance From Origin (bp)
<i>Clal</i>	1	410
<i>KpnI</i>	3	500, 3890, 4280
<i>PvuI</i>	1	1120
<i>SaI</i>	1	2900
<i>PvuII</i>	1	4135
<i>EcoRV</i>	2	3690, 3890
<i>BglII</i>	1	4500
<i>XmaI</i>	1	4800

The genomic clones pPG 6.0, pPG 4.0 and pPG 4.8 were manipulated by insertion into unique restriction sites on the *E. coli* plasmid pBR322. Clone pPG 6.0, which is a *HindIII* fragment, was conveniently cloned into the *HindIII* site of pBR322. Clone pPG 4.0 was cloned into the *EcoRI-PvuII* sites of pBR322 and clone pPG 4.8 was cloned into the *EcoRI-BamHI* sites of pBR322. (See Example VI). *E. coli* strains transformed with these plasmids have been deposited with the Northern Regional Research Center, Peoria, Illinois, to insure free access to the public upon issuance of a patent on this application. The deposited strains have been given the following accession numbers:

Genomic Class	Laboratory Designation	Accession No.
pPG 6.0	LE392-pPG 6.0	NRRL B-15867
pPG 4.0	LE392-pPG 4.0	NRRL B-15868
pPG 4.8	LE392-pPG 4.8	NRRL B-15869

Figures 7, 8 and 9 provide restriction map data for the 3' regulatory regions of the polypeptides p76, p72 (alcohol oxidase) and p40, respectively. The 3' regulatory regions are useful in controlling the polyadenylation, termination of transcription and termination of translation of messenger RNA which is coded for by preceding nucleotide sequences. Thus, the 3' regulatory region from the polypeptide p76 gene, a 2.7 kilobase pair *EcoRI-HindIII* fragment illustrated in Figur 7, is useful in controlling the



polyadenylation as well as termination of transcription and termination of translation of the mRNA which codes for polypeptide p76, or any other mRNA derived from a gene inserted upstream of the 3' regulatory region. The 0.2 kilobase pair *StuI-PvuII* fragment from the p72 gene detailed in Figure 8a, the 0.3 kilobase pair *StuI-HindIII* fragment from the p72 gene detailed in Figure 8b, the 3.2 kilobase pair *SalI-EcoRI* fragment from the p72 gene and the 1.9 kilobase pair *SalI-EcoRI* fragment from the p40 gene detailed in Figure 9 have similar utility, both with respect to the structural genes with which they are associated in the wild type *Pichia pastoris* and any foreign (i.e. heterologous) genes which may be inserted upstream of these 3' regulatory regions.

Since the alcohol oxidase gene in pPG4.0 terminates within a few hundred base pairs of the AO gene transcription termination site, the additional 3' sequence detailed in Figure 8c was obtained as follows. The first step was to digest *Pichia* chromosomal DNA with *EcoRI* and *SalI* and hybridize the digested DNA with a 2.0 kbp <sup>32</sup>P-labelled *BamHI-HindIII* fragment from the AO gene by the Southern blot method. Among the *Pichia* *EcoRI-SalI* digestion fragments which hybridized with the AO gene probe was a 3.2 kbp fragment which encodes the 3' portion of the AO gene and sequences flanking the 3' terminus of the gene.

The 3' AO gene fragment was then cloned by recovering *EcoRI-SalI*-cut *Pichia* DNA fragments of about 3.2 kbp by gel elution and inserting the fragments into *EcoRI* and *SalI*-digested pBR322. Finally, a recombinant plasmid, pPG3.2, which contains the 3' AO gene fragment was identified by colony hybridization using the labelled AO gene fragment as probe. An *E. coli* strain transformed with plasmid pPG3.2 has been deposited with the Northern Regional Research Center, Peoria, Illinois. The deposited strain has been assigned accession number NRRL B-15999. Figure 8c shows a restriction endonuclease cleavage site map of the *Pichia* DNA fragment from pPG3.2. The fragment contains about 1.5 kbp encoding the 3' portion of the AO (from *SalI* to *HindIII*) and about 1.7 kbp of sequence 3' of the AO gene.

#### Characterization of cDNA Clones

The cDNA clones for the regulatable genes from *Pichia pastoris* have also been characterized by restriction mapping. In Figure 12, the p76 cDNA, a 1.1 kilobase pair fragment is detailed. Referring to the 5' end of the DNA sequence as the origin, restriction enzyme *XhoI* cleaves p76 cDNA about 500 base pairs from the origin, *HincII* cleaves about 950 base pairs from the origin and *EcoRI* cleaves p76 cDNA about 1050-1100 base pairs from the origin. The cDNA clone shown in Figure 12, as well as the cDNA clones shown in Figures 13 and 14 are all shown with *PstI* termini. These are artificially created restriction sites produced by G-C tailing of the initially obtained complementary DNA to facilitate cloning of the DNA fragments into pBR322. Based on Northern hybridization studies and the size of the polypeptide product, it is estimated that the cDNA clone pPC 15.0 is an incomplete copy of p76 mRNA, representing only about half of the total messenger RNA sequence.

In Figure 13, a composite restriction map for p72 (alcohol oxidase) cDNA, constructed by overlap of clones pPC 8.3 and pPC 8.0, is presented. As above, the 5' end of the DNA sequence is referred to as the origin. Thus, treating alcohol oxidase cDNA with a variety of restriction enzymes gives the following size fragments:

Restriction Enzyme	Cleavage Sites	Distance From Origin (bp)
<i>AsuII</i>	2	20, 420
<i>EcoRV</i>	1	50
<i>BamHI</i>	2	80, 90
<i>HincII</i>	1	550
<i>SalI</i>	1	820
<i>BglII</i>	1	820
<i>KpnI</i>	1	850
<i>XbaI</i>	1	1450
<i>RsaI</i>	1	1760
<i>StuI</i>	1	2000

Restriction enzyme mapping of the 3' end of the alcohol oxidase gene in clones pPC 8.0 and pPC 8.3 revealed that cDNA clone pPC 8.3 is missing approximately 250 nucleotides of the alcohol oxidase mRNA sequence (Figure 2). The sequences present at the 3' end of the alcohol oxidase mRNA are present in cDNA clone pPC 8.0 which overlaps pPC 8.3 by approximately 500 nucleotides.

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Figure 14 presents a restriction map for the cDNA of polypeptide p40, a 1.2 kilobase pair fragment. Referring to the 5' end of the cDNA clone as the origin, clone pPC 6.7 is cleaved by *Sal*I (and *Hinc*II) about 1000 bases from the origin.

Each of the cDNA fragments have been cloned into pBR322, which is then transformed into *E. coli*. The transformed strains have been deposited with the Northern Regional Research Center in Peoria, Illinois. The deposited strains have been assigned the following accession numbers:

cDNA clone	Laboratory Description	Accession No.
pPC 15.0	LE392-pPC 15.0	NRRL B-15870
pPC 8.3	LE392-pPC 8.3	NRRL B-15871
pPC 8.0	MM294-pPC 8.0	NRRL B-15873
pPC 6.7	LE392-pPC 6.7	NRRL B-15872

Each of the above-described cDNA clones are useful as probes for the identification and isolation of chromosomal DNA encoding the production of polypeptides unique to the growth of yeast on methanol as a carbon and energy source. Hence as already described, these clones were used to identify *P. pastoris* chromosomal DNA fragments containing the regulatory regions and structural coding information for the unique polypeptides which are observed when *P. pastoris* is grown on methanol. In a similar fashion, these cDNA clones have utility as probes for the identification and isolation of analogous genes from other methanol assimilating yeasts such as, for example, *Torulopsis molischiana*, *Hansenula capsulatum*, *H. nonfermentans* and the like (See Example XVII).

## Detailed Analysis of the Alcohol Oxidase Gene

The 5' regulatory region of clone pPG 4.0 was further characterized by determining the nucleotide sequence of the clone upstream (5') of the point where the structural information for p72 (alcohol oxidase) is encoded. The first 250 nucleotides prior to the mRNA translation start site (ATG codon) are believed to be:

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30      5' - ATGCTTCCAA      GATTCTGGTG      GGAATACTGC      TGATAGCCTA
          ACGTTCATGA      TCAA AATTTA      ACTGTTCTAA      CCCCTACTTG
          GACAGGCAAT      ATATAAACAG      AAGGAAGCTG      CCCTGTCTTA
35      AACCTTTTTT      TTTATCATCA      TTATTAGCTT      ACTTTCATAA
          TTGCGACTGG      TTCCAATTGA      CAAGCTTTTG      ATTTTAACGA
          CTTTAAACGA      CAACTTGAGA      AGATCAAAAA      ACAACTAATT
40      ATTCGAAACG - 3' .

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## Sequence C

The promoter function of clone pPG 4.0 is believed to be contained within this sequence of nucleotide bases.

In order to more fully describe this novel DNA fragment, an additional 301 nucleotides further upstream of the sequence detailed in Sequence C above have been determined. Thus, the first 551 nucleotides prior to the mRNA translation start site are believed to be:

5'	AATGGCCCAA	CTGACAGTTT	AAACGCTGTC	TTGGAACCTA
	ATATGACAAA	AGCGTGATCT	CATCCAAGAT	GAAC TAAGTT
5	TGGTTCGTTG	AAATCCTAAC	GGCCAGTTGG	TCAAAAAGAA
	ACTTCCAAAA	GTCGCCATAC	CGTTTGTCTT	GTTTGGTATT
	GATTGACGAA	TGCTCAAAAA	TAATCTCATT	AATGCTTAGC
10	GCAGTCTCTC	TATCGCTTCT	GAACCCGGTG	GCACCTGTGC
	CGAAACGCAA	ATGGGGAAAC	AACCCGCTTT	TTGGATGATT
	ATGCATTGTC	CTCCACATTGT	ATGCTTCCAA	GATTCTGGTG
15	GGAATACTGC	TGATAGCCTA	ACGTTTCATGA	TCAAAATTTA
	ACTGTTCTAA	CCCCTACTTG	GACAGGCAAT	ATATAAACAG
	AAGGAAGCTG	CCCTGTCTTA	AACCTTTTTT	TTTATCATCA
	TTATTAGCTT	ACTTTCATAA	TTGCGACTGG	TTCCAATTGA
20	CAAGCTTTTG	ATTTTAACGA	CTTTTAACGA	CAACTTGAGA
	AGATCAAAAA	ACAACTAATT	ATTCGAAACG	3'

#### Sequence D

The additional nucleotides contained in Sequence D (compared to Sequence C) are believed to impart, by an unknown mechanism, additional regulatory functions to the promoter region contained within Sequence C. It should be recognized that Sequence D represents only partial DNA sequencing for the 1.1 kbp DNA fragment shown in Examples XIV and XV to be capable of controlling gene expression in yeast. It may be that additional control functions are encoded in the portion of the 1.1 kbp DNA fragment not detailed in Sequence D.

In order to further describe this novel 1.1 kbp DNA fragment, additional nucleotide sequencing was carried out to fully delineate the nucleotide sequence of the entire 1.1 kbp DNA fragment shown in Examples XIV and XV to be capable of controlling gene expression in yeast. The nucleotide sequence is set forth as Sequence D':

			5'-AGATCTAA	CATCCAAAGA
	CGAAAGGTTG	AATGAAACCT	TTTGGCCATC	CGACATCCAC
5	AGGTCCATTC	TCACACATAA	GTGCCAAACG	CAACAGGAGG
	GGATACACTA	GCAGCAGACG	TTGCAAACGC	AGGACTCATC
	CTCTTCTCTA	ACACCATTTT	GCATGAAAAC	AGCCAGTTAT
	GGGCTTGATG	GAGCTCGCTC	ATTCCAATTC	CTTCTATTAG
10	GCTACTAACA	CCATGACTTT	ATTAGCCTGT	CTATCCTGGC
	CCCCCTGGCG	AGGTCATGTT	TGTTTATTTT	CGAATGCAAC
	AAGCTCCGCA	TTACACCCGA	ACATCACTCC	AGATGAGGGC
15	TTTCTGAGTG	TGGGGTCAAA	TAGTTTCATG	TTCCCAAATG
	GCCCCAACT	GACAGTTTAA	ACGCTGTCTT	GGAACCTAAT
	ATGACAAAAG	CGTGATCTCA	TCCAAGATGA	ACTAAGTTTG
	GTTCGTTGAA	ATCCTAACGG	CCAGTTGGTC	AAAAAGAAAC
20	TTCCAAAAGT	CGCCATACCG	TTTGTCTTGT	TTGGTATTGA
	TTGACGAATG	CTCAAAAATA	ATCTCATTAA	TGCTTAGCGC
	AGTCTCTCTA	TCGCTTCTGA	ACCCGGTGGC	ACCTGTGCCG
25	AAACGCAAAT	GGGGAAACAA	CCCGCTTTTT	GGATGATTAT
	GCATTGTCCT	CCACATTGTA	TGCTTCCAAG	ATTCTGGTGG
	GAATACTGCT	GATAGCCTAA	CGTTCATGAT	CAAAATTTAA
30	CTGTTCTAAC	CCCTACTTGG	ACAGGCAATA	TATAAACAGA
	AGGAAGCTGC	CCTGTCTTAA	ACCTTTTTTT	TTATCATCAT
	TATTAGCTTA	CTTTCATAAT	TGCGACTGGT	TCCAATTGAC
35	AAGCTTTTGA	TTTAAACGAC	TTTAAACGAC	AACTTGAGAA
	GATCAAAAAA	CAACTAATTA	TTCGAAACG-3'.	

#### Sequence D'

It is recognized by those of skill in the art that additional control functions, relative to Sequences C and D, may be encoded in that portion of sequence D' which is further upstream (i.e., in the 5' direction) of the nucleotide sequence detailed in sequences C and D.

To determine where RNA transcription for the alcohol oxidase gene is initiated, the DNA sequences around the 5' end of this gene from the genomic clone pPG 4.0 and the cDNA clone pPC 8.3 were compared. cDNA clone pPC 8.3 contains about 100 nucleotides of an untranslated region 5' to the alcohol oxidase gene. Based upon this sequence, an oligonucleotide of 15 bases (5'-CTTCTCAAGTTGTCTG-3'); complementary with respect to nucleotides -29 to -43, where the A of the translation start site (ATG codon) is designated as +1 and the G in the 5' direction is designated as -1, was synthesized (See Example IX) and used as a primer to extend along the alcohol oxidase mRNA to reach the 5' end. The sequence of cDNA obtained from this primer-extension experiment revealed three different transcriptional initiation points for *Pichia pastoris* alcohol oxidase mRNA. The major transcript begins 114 nucleotides from the translational initiation codon. Two minor alternative transcripts begin 117 and 111 nucleotides upstream (5') from the alcohol oxidase AUG codon.

The 55 nucleotides preceding the start of alcohol oxidase mRNA contain a putative Goldberg-Hogness box (TATAA box). The sequence TATAAA occurs at position -40 from the 5' end of the predominant transcript for alcohol oxidase mRNA and therefore 165 nucleotides upstream from the initiation codon for

this protein.

The 3' regulatory region of the alcohol oxidase gene was further characterized by determining the nucleotide sequence for about 120 nucleotides downstream of the point where the structural information for p72 (alcohol oxidase) is encoded. The sequence is set forth below as Sequence D":

5

5'	-TCAAGAGGAT	GTCAGAATGC	CATTTCCTG	AGAGATGCAG
	GCTTCATTTT	TGATACTTTT	TTATTTGTAA	CCTATATAGT
10	ATAGCATTTT	TTTTGTCAAA	AAAAAAAAAA	AAAAAAAAAA-3'

Sequence D"

15

#### Detailed Analysis of the p76 Gene

The 5' regulatory region of the clone pPG 6.0 was also further characterized by determining the nucleotide sequence of the clone upstream (5') of the point where the structural information for p76 is encoded. The first 622 nucleotides prior to the mRNA translation start site (ATG codon) are believed to be:

			5'-TT
25	CACCCATACA	ACTATAAACC	TTAGCAATTG
	AATTCATTGT	TCCGAGTTTA	ATATACTTGC
	AACCAAGGGA	TTTCAGCTTC	CTTACCCCAT
	TTCCATTTAC	CCCCCACTGG	AGAGATCCGC
30	AGATAATAGA	AAAAACAAT	TCGGACAAAT
	CTCAGCCAAT	TAAAGTCATT	CCATGCACTC
	CCGTTCCATC	CCTTTGTTGA	GCAACACCAT
35	TACGAAAGAG	GAAACTTAAC	CGATACCTTG
	AGGCGCGAAT	GAGTTTAGCC	TAGATATCCT
	TGTCCGATAC	TTCTCCACAT	TCAGTCATAG
40	TGTATCATGA	AGAGACGGAA	ACGGGCATAA
	CAAATTATAT	AAAGACAACA	TGCCCCAGTT
	CTTTCCTATT	CTTGTATCCT	GAGTGACCGT
	ATAAAAAGTT	CGTTTTAACT	TAAGACCAAA
45	ACAAATTATA	ACCCCTCTAA	ACACTAAAGT
	CAAACTATCA	AACATCAAAA-3'	

#### Sequence D'''

50

The promoter function of clone pPG 6.0 is believed to be contained within this sequence of nucleotide bases, although those of skill in the art recognize that additional regulatory properties may be imparted by sequences further upstream than the sequences presented as Sequence D'''.

55 The 3' regulatory region of clone pPG 6.0 was further characterized by determining the nucleotide sequence for about 180 nucleotides downstream (3') of the point where the p76 structural information is encoded. The sequence is set forth below as Sequence D'''':

15 The above-described plasmids of the present invention have utility in yeast strains which can be transformed. Regulation of gene expression in yeast by the novel DNA fragments of the present invention can be accomplished by subjecting the transformed organisms to carbon source starvation. Carbon source starvation after growth on a variety of both catabolite repressing and non-catabolite repressing carbon  
20 sources induces expression of the gene product maintained under the control of the regulatory regions of the invention. Another means to achieve expression of the desired gene product in appropriate species of transformed yeast is to grow transformed yeasts on methanol. Yet another means to induce expression of the desired gene product is to grow transformed yeast on media containing non-catabolite repressing carbon sources.

Transformed yeast strains which are preferred in the process of the present invention include members of the genera:

Yeasts from these genera are preferred because their safety of handling, growth conditions and the like have been established and are well known to those of skill in the art.

*Candida*,  
*Kloeckera*,  
*Saccharomyces*,  
*Rhodotorula*,  
*Hansenula*,  
*Torulopsis*, and  
*Pichia*.

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glycerol,  
ethanol,  
lactose,  
galactose,  
5 fructose,  
sucrose,

and the like and mixtures of any two or more thereof are also useful in the practice of the invention. By growing the host organism on a suitable non-catabolite repressing non-methanolic carbon source such as, for example, glycerol and galactose, or by growing the host organism on a suitable catabolite repressing carbon source such as, for example, ethanol, glucose and fructose, then subjecting the host organism to carbon source starvation conditions, expression of a gene product under the control of the regulatory regions of the invention can be achieved.

In addition, since the regulatory regions of the invention are responsive to a variety of growth conditions, both in terms of induction and repression of expression, the regulated expression of a gene product under the control of the regulatory regions of the invention can be achieved. Thus, for example, cells can be grown on a carbon source which induces only low levels of foreign gene expression, then switched to methanol which will strongly induce gene expression. Alternatively, regulated gene expression can be achieved by employing mixtures of inducing/repressing feeds such as, for example, methanol-glucose mixtures. As yet another alternative, high expression levels produced by growth on methanol can be reduced as desired by addition to the growth media of a repressing carbon source such as glucose or ethanol. Of course, those of skill in the art recognize that other variations of feed mixtures and order of feed introduction are possible, and afford a great deal of control over the level of gene expression obtained from the invention regulatory regions.

An especially preferred host yeast strain is the mutant *Pichia pastoris* GS115, which is a mutant defective in the ability to produce histidine, and has thus been designated as having the mutant genotype *his4*. GS115 is derived from *Pichia pastoris* NRRL Y-11430 and has been deposited with the Northern Regional Research Center of the United States Department of Agriculture in Peoria, Illinois. *Pichia pastoris* GS115 has been assigned the accession number NRRL Y-15851, as of August 31, 1984. This particular host is useful because it is an auxotrophic mutant deficient in the histidine pathway. Transformation of this host with a vector containing, among other DNA sequences, the *HIS4* gene function, allows ready selection for transformed host.

Since the regulatory regions of the present invention have also been demonstrated to be useful for the regulated expression of heterologous gene products in yeast strains of the genus *Saccharomyces*, for which a large number of auxotrophic mutants are known, additional preferred host yeast strains include ATCC 24683 (a *trp1 ade1, his2, leu1, gal1, ura1* mutant), ATCC 24684 (a *trp1, ade1, his7, gal1, ura1* mutant), ATCC 32810 (a *trp5, arg4, his5, lys1, ade2, gal2* mutant), ATCC 34182 (an *ade3, his, lys, ura* mutant), ATCC 34352 (an *ura2* mutant), ATCC 34353 (an *ura2* mutant), ATCC 38523 (an *arg1, thr1* mutant), ATCC 38626 (a *leu2, his4* mutant), ATCC 38680 (a *his4, leu2, thr4* mutant), ATCC 42243 (an *ura3* mutant), ATCC 42336 (an *ade1, his4, thr4* mutant), ATCC 42403 (an *arg4, lys7* mutant), ATCC 42404 (an *ade1, his4, leu2* mutant), ATCC 42584 (an *ura1, his6* mutant), ATCC 42596 (a *his4, leu2, lys1* mutant), ATCC 42957 (a *his4, leu2, thr4, trp5* mutant), ATCC 42950 (an *ade* mutant), ATCC 42951 (an *ade, leu* mutant), ATCC 44069 (an *ura1* mutant), ATCC 44070 (a *leu2, his4* mutant), ATCC 44222 (a *his4* mutant), ATCC 44376 (a *his4, ade2* mutant), ATCC 44377 (a *his4, leu1* mutant), and the like are readily accessible to those of skill in the art.

It is recognized by those of skill in the art that useful host strains are not limited to auxotrophic mutants. Thus, transformation of prototrophic strains with positive selection markers, such as, for example, antibiotic resistance genes, also provides a useful means for the detection and isolation of transformed strains.

*Escherichia coli* is also a suitable host for the plasmids of the invention. Those of skill in the art recognize that many strains of *E. coli* are suitable hosts. Several strains employed in the present work are summarized below:

Strain designation	Accession Number
MC1081	None known
LE392	ATCC #33572
MM294	ATCC #33625

*Pichia pastoris* Transformation Proc dur

The transformation of *Pichia pastoris* has not been previously described. The experimental procedures for transformation of *Pichia pastoris* are presented in greater detail below (Example XII). In order to develop a transformation system for *P. pastoris*, the auxotrophic mutant GS115 (NRRL Y-15851) was isolated and determined to be defective in the histidine pathway in that the strain has no detectable histidinol dehydrogenase activity.

GS115 (NRRL Y-15851) can be transformed by enzymatic digestion of the cell walls to give spheroplasts; the spheroplasts are then mixed with the transforming DNA and incubated in the presence of calcium ions and polyethylene glycol, then regenerated in a medium deficient in histidine. The transforming DNA includes the HIS4 gene in which the host strain is deficient, thus only transformed cells survive on the selective growth medium employed.

Isolation of *Pichia pastoris* HIS4 Gene

The HIS4 gene was isolated from the strain *P. pastoris* NRRL Y-11430 by partial digestion of total chromosomal DNA with *Sau3A* followed by centrifugation through sucrose gradients. (See Example XIII). Fragments of 5 to 20 kbp were cloned into the *Bam*HI cleavage site of the *S. cerevisiae*-*E. coli* shuttle vector YEp13 (ATCC 37115; Figure 33) and transformed into *E. coli*. Approximately 50,000 colonies were combined and total plasmid DNA extracted. Spheroplasts of *S. cerevisiae* strain 5799-4D (NRRL Y-15859), a *his4ABC* mutant, were mixed with about 1 µg of the YEp13 *Pichia* DNA library by the procedure of Hinnen *et al* (1978) and allowed to regenerate in a medium deficient in histidine. The transformation resulted in about  $1 \times 10^3$  prototrophic yeast colonies from a population of  $5 \times 10^7$  total regenerable spheroplasts. A parallel control sample incubated without DNA produced no colonies. Total yeast DNA was extracted from 20 of the His<sup>+</sup> colonies and transformed back into *E. coli*. Seventeen of the yeast DNA preparations produced ampicillin resistant colonies. These cloned fragments were further characterized by restriction enzyme sizing and mapping as well as by their ability to cross hybridize with a labelled *S. cerevisiae* HIS4 fragment at low stringency (post hybridization washes in 2xSSC at 55°C by the method described in Example XIII, §G. The HIS4-containing plasmids each contained one or more fragments which hybridized to the *S. cerevisiae* HIS4 gene. One such HIS4-containing plasmid was recloned to give a HIS4-containing plasmid designated pYJ8 and is shown in Figure 25. Plasmid pYJ8 contains pBR325 sequences, including chloramphenicol and ampicillin resistance genes, as well as the *Pichia* HIS4 gene.

The ARG4 gene was isolated from *P. pastoris* NRRL Y-11430 employing an analogous protocol and the Arg<sup>-</sup> *S. cerevisiae* strain S2072A (a *arg4 leu2 trp1 gal2* mutant; obtained from the Yeast Genetic Stock Center, Berkely, CA).

Those of skill in the art recognize that other marker genes from *Pichia* can similarly be isolated employing appropriately deficient *S. cerevisiae* strains.

Isolation of *Pichia pastoris* Autonomous Replication Sequences

Another useful component of the vectors of the present invention are *Pichia*-derived autonomous replication sequences (PARS), which enhance both the transformation frequency of GS115 (NRRL Y-15851) and the maintenance of plasmid as a stable extrachromosomal element.

To search for *Pichia* ARSs, DNA from *Pichia pastoris* GS115 (NRRL Y-15851) was partially digested with *Taq*I and 5 to 10 kbp fragments were isolated and cloned into the unique *Cla*I site of pYJ8Δ*Cla*. (See Figure 26). Plasmid DNA was recovered from about 10,000 His<sup>+</sup> *Pichia* colonies and used to transform *E. coli*. Plasmids from about 10,000 ampicillin resistant colonies were isolated and then transformed back into GS115. Forty of the His<sup>+</sup> yeast colonies from this sublibrary transformation were separately streaked onto selective medium and grown in separate cultures in selective medium. Total yeast DNA was extracted from each of these 40 cultures and transformed into *E. coli*. Two plasmids, pYA63 (PARS1) and pYA90 (PARS2) whose yeast DNA preparations produced the most ampicillin resistant *E. coli* colonies, were selected for further analysis. Both of these plasmids transformed *Pichia pastoris* GS115 (NRRL Y-15851) at a very high frequency and each contained an insert of foreign DNA.

As a measure for the ability of the ARSs to maintain plasmids as autonomous elements in *Pichia*, cultures of yeast cells which had been transformed with each plasmid were grown in selective medium and periodically sampled. The state of the plasmid sequences in the cells was determined by Southern hybridization of unrestricted yeast DNAs to radioactively labeled pBR325. Plasmids pYA63 and pYA90 were maintained in *Pichia* for at least 10 generations in the selective medium (but had integrated by 50



generations).

One of the putative *Pichia* autonomous replication sequences (PARS1) was cloned into several other *Pichia* vectors to examine its ability to maintain the transforming DNA as an autonomous element. Plasmids pYJ30 (Figure 27) and pBPf1 (Figure 34) were still present as autonomous elements after 20 generations of growth on selective media (His<sup>-</sup>) and were present in multi-copies per cell. Southern blot analysis of cells transformed with pYJ30 indicate about 10 copies per cell.

To determine if plasmids pSAOH5 (see Figure 18) and pT76H4 (See Figure 22b), which contain PARS1 contributed by pYJ30 and pBPf1, respectively, display similar stability to the plasmids from which they were derived, cells containing these vectors were grown under selective conditions for about 50 generations under selective conditions (His<sup>-</sup>) in the presence of glucose. The cells were then shifted to non-selective conditions (His<sup>+</sup>) and the loss of prototrophy was monitored. The stability of these plasmids was comparable to the stability of pYJ30, including the rapid loss of His prototrophy upon shift to non-selective media. Thus, it is believed that experiments carried out with plasmids containing the autonomous replication sequence, PARS1, provide results of gene expression from autonomous plasmid DNA.

#### Novel $\beta$ -Galactosidase Gene Containing Constructs

In order to demonstrate the ability of the regulatory regions of the present invention to control the production of protein products, novel DNA constructs were prepared. Thus the *E. coli lacZ* gene was placed in several plasmids under the control of the regulatory regions of the genes encoding polypeptide p72 (alcohol oxidase) or p76. The preparation of plasmids pSAOH1, pSAOH5, pSAOH10, pTAFH.85, pT76H1, pT76H2, pT76H3 and pT76H4 is described in Example XIV.

Although the introduction of the regulatory region - $\beta$ -galactosidase gene fusions of the invention into host yeast cells is described herein employing plasmids as the vehicle for introduction, those of skill in the art recognize that it is not necessary for the regulatory region-structural gene construct to be introduced into the cell via a plasmid. Hence, any molecule capable of being maintained in yeast can be employed. Therefore, the regulatory region-structural gene constructs of the invention can be manipulated via vectors other than plasmids. Alternatively, the regulatory region-structural gene construct can be integrated into the chromosome of the host yeast cell.

Those of skill in the art also recognize that the scope of the present invention is not limited to the production of  $\beta$ -galactosidase under the regulation of the regulatory regions disclosed herein. The variety of polypeptides which can be produced under the regulation of the regulatory regions of the invention is limited only by the imagination of the reader. Many procedures exist for the preparation of DNA sequences which code for desired polypeptides. For example, oligonucleotides of various lengths can be synthesized by known procedures. Several such oligonucleotides can be assembled, in consequence of the specific base pairing properties thereof, into longer, double-stranded molecules. The component oligonucleotides of this double-stranded molecule can be joined (ligated) by the enzyme DNA ligase. Alternatively, DNA molecules having the desired coding sequence can be synthesized by use of the enzyme reverse transcriptase, using messenger RNA related to the desired polypeptide as a template for the action of reverse transcriptase. Yet another possibility is the cloning of genomic DNA fragments and observing whether direct expression of the desired product occurs.

The DNA sequence which codes for the desired polypeptide can be modified for preparation of the regulatory region-structural gene construct by a variety of procedures. For example, the ends of the DNA prepared as described above can be ligated with the enzyme DNA ligase to short double-stranded DNA molecules which contain the nucleotide sequence recognized by specific restriction endonucleases, so called linker molecules. Digestion of these molecules with a specific restriction endonuclease following the ligation will generate termini corresponding to the specified restriction endonuclease recognition site at the ends of the prepared DNA sequence.

Three specific regulatory region- $\beta$ -galactosidase gene constructs prepared in the course of this work are described in terms of restriction mapping data presented in Figures 15 and 16. The restriction map presented in Figure 15a describes a construct comprising a 0.85 kilobase pair *HindIII-BamHI* portion derived from the 5' regulatory region of pPG 6.0 and the *lacZ* gene from *E. coli* (the 3.6 kilobase pair *BamHI-NruI* fragment shown). This same construct is present in each of the plasmids pTAFH.85, pT76H1 and pT76H2, to be described in greater detail below. (See Example XIV). The restriction map presented in Figure 15b describes a construct comprising a 1.3 kilobase pair *HindIII-EcoRI* portion derived from the 5' regulatory region of pPG 6.0 and the *lacZ* gene from *E. coli*. This same construct is present in each of the plasmids pT76U1, pT76H3 and pT76H4, to be described in greater detail below (see Example XIV).

Figure 16 is a restriction map of a construct comprising a 1.1 kilobase pair *EcoRI-BamHI* fragment

derived from a portion of the 5' regulatory region of pPG 4.0 and the *lacZ* gene from *E. coli*. This construct is present in each of the plasmids pSAOH1, pSAOH5 and pSAOH10, to be described in greater detail below. (See Example XIV).

Plasmid pSAOH1 is illustrated schematically in Figure 17. In addition to containing the regulatory region- $\beta$ -galactosidase gene fusion detailed in Figure 16, the plasmid is shown to contain:

- (a) pBR322 sequences, including the *Amp<sup>R</sup>* gene;
- (b) *Pichia pastoris* HIS4 gene;
- (c) *S. cerevisiae* 2 $\mu$  circle DNA; and
- (d) the interrupted URA3 gene from *S. cerevisiae*.

The plasmid therefore has the capability to transform and replicate in *E. coli* hosts and yeast hosts. Selectable markers are present for manipulation of the DNA in either *E. coli* or yeast hosts.

Plasmid pSAOH5 is illustrated schematically in Figure 18. The plasmid is similar to pSAOH1 described above, except the *S. cerevisiae* 2 $\mu$  circle DNA and some of the *Pichia pastoris* HIS4 gene flanking DNA has been deleted while a *Pichia pastoris* autonomously replicating sequence (PARS1 from pYA63) has been added.

Plasmid pSAOH10 is illustrated schematically in Figure 19. The plasmid contains:

- (a) regulatory region- $\beta$ -galactosidase gene fusion;
- (b) pBR325 sequences, including genes conferring tetracycline resistance, chloramphenicol resistance and ampicillin resistance (*ter<sup>R</sup>*, *cam<sup>R</sup>* and *amp<sup>R</sup>*, respectively); and
- (c) *S. cerevisiae* HIS4 gene (obtained from plasmid pYA2 as described below).

Plasmids pTAFH.85, pT76H1 and pT76H2 are analogous to the above three described plasmids, except the regulatory region- $\beta$ -galactosidase gene fusion employed was that described in Figure 15a (instead of the fusion described in Figure 16).

Plasmids pT76H3 and pT76H4 are analogous to pSAOH1 and pSAOH5, respectively, except the regulatory region- $\beta$ -galactosidase gene fusion employed was that described in Figure 15b (instead of the fusion described in Figure 16).

Plasmid pTAFH.85 is illustrated schematically in Figure 20 and comprises:

- (a) the regulatory region- $\beta$ -galactosidase gene fusion shown in Figure 15a;
- (b) pBR322 sequences, including the *amp<sup>R</sup>* gene;
- (c) *Pichia pastoris* HIS4 gene;
- (d) *S. cerevisiae* 2 $\mu$  circle DNA; and
- (e) the interrupted URA3 gene from *S. cerevisiae*.

Plasmid pT76H1 is illustrated schematically in Figure 21 and comprises:

- (a) the regulatory region- $\beta$ -galactosidase gene fusion shown in Figure 15a;
- (b) pBR322 sequences, including the *amp<sup>R</sup>* gene; and
- (c) *Pichia pastoris* HIS4 gene and autonomously replicating sequence (PARS1).

Plasmid pT76H2 is illustrated schematically in Figure 22 and comprises:

- (a) the regulatory region- $\beta$ -galactosidase gene fusion shown in Figure 15a;
- (b) pBR325 sequences, including genes conferring tetracycline resistance, chloramphenicol resistance and ampicillin resistance; and
- (c) *S. cerevisiae* HIS4 gene.

Plasmid pT76H3 is illustrated schematically in Figure 22a and comprises:

- (a) the regulatory region- $\beta$ -galactosidase gene fusion shown in Figure 15b;
- (b) pBR322 sequences, including the *amp<sup>R</sup>* gene;
- (c) *P. pastoris* HIS4 gene;
- (d) *S. cerevisiae* 2 $\mu$  circle DNA; and
- (e) the interrupted URA3 gene from *S. cerevisiae*.

Plasmid pT76H4 is illustrated schematically in Figure 22b and comprises:

- (a) the regulatory region- $\beta$ -galactosidase gene fusion shown in Figure 15b;
- (b) pBR322 sequences, including the *amp<sup>R</sup>* gene;
- (c) *Pichia pastoris* HIS4 gene; and
- (d) *Pichia pastoris* autonomous replication sequence (PARS1).

#### Expression of $\beta$ -Galactosidase in Yeast

*Pichia pastoris* GS115 (NRRL Y-15851) was transformed with the novel  $\beta$ -galactosidase gene-containing constructs described above. Several of the resulting transformed yeast strains have been deposited with the Northern Regional Research Center of the United States Department of Agriculture and

assigned deposit accession numbers as follows:

Host	Plasmid	Accession Number of Transformed Strain
GS115	pSAOH1	NRRL Y-15852
GS115	pSAOH5	NRRL Y-15853
GS115	pSAOH10	NRRL Y-15854
GS115	pTAFH.85	NRRL Y-15855
GS115	pT76H1	NRRL Y-15856
GS115	pT76H2	NRRL Y-15857

The novel  $\beta$ -galactosidase gene-containing constructs were also used to transform *E. coli*. Transformed bacterial strains have also been deposited with the Northern Regional Research Center in Peoria, Illinois. The transformed strains have been assigned the following accession numbers:

Host	Plasmid	Accession Number of Transformed Strain
MC1061	pSAOH1	NRRL B-15861
MC1061	pSAOH5	NRRL B-15862
MC1061	pSAOH10	NRRL B-15863
MC1061	pTAFH.85	NRRL B-15864
MC1061	pT76H1	NRRL B-15865
MC1061	pT76H2	NRRL B-15866
MC1061	pTA013	NRRL B-15875
MC1061	pT76H3	NRRL B-18000
MC1061	pT76H4	NRRL B-18001
MC1061	pT76U1	NRRL B-18002

*Pichia pastoris* GS115(NRRL Y-15851) transformed with each of the first eight plasmids described above which contain the alcohol oxidase and p76 regulatory region-*lacZ* gene fusions of the invention were grown to stationary phase on minimal medium supplemented with biotin plus glucose as carbon source. Once cells reached stationary phase, they were shifted to minimal medium supplemented with biotin plus methanol as carbon source. After cells had grown for about 3-5 generations at 30°C, they were shifted to fresh minimal medium supplemented with biotin and grown on glucose or methanol as carbon source. At distinct time points, culture samples were withdrawn and analyzed for the presence of  $\beta$ -galactosidase and alcohol oxidase by methods detailed in Examples VII and XV.

It was found that cells grown on glucose as carbon source produced no detectable levels of  $\beta$ -galactosidase or alcohol oxidase, while cells grown on methanol as sole carbon source expressed significant levels of both alcohol oxidase and  $\beta$ -galactosidase. It was also found that the glucose grown cells, when subjected to conditions of carbon source starvation, also expressed measurable quantities of alcohol oxidase as well as  $\beta$ -galactosidase. Thus, it is clear that the regulatory regions of the invention are responsive to both the presence of methanol as well as conditions of carbon source starvation.

As verification that the regulatory regions of the invention are responsive to growth on non-catabolite repressing carbon sources as well as conditions of carbon source starvation, a plasmid containing the alcohol oxidase regulatory region, pTA013; and a plasmid containing the p76 regulatory region, pT76U1, was used to transform a non-methanol utilizing strain of yeast, *Saccharomyces cerevisiae*. One of the transformed strains employed, having the laboratory designation of SEY2102-pTA013 has been deposited with the Northern Regional Research Center in Peoria, Illinois. The transformed strain has been assigned accession number NRRL Y-15858. *Saccharomyces cerevisiae* NRRL Y-15858 and SEY2102-pT76U1 were grown up on glucose, fructose, ethanol, glycerol and galactose for about five generations then subjected to conditions of carbon source starvation. The usual assay for  $\beta$ -galactosidase (See Example XV) after five generations indicated that glycerol and galactose grown cells produced large amounts of  $\beta$ -galactosidase while glucose and fructose grown cells produced essentially no  $\beta$ -galactosidase. When  $\beta$ -galactosidase was measured after 6 hours under carbon source starvation, the production of moderate quantities of  $\beta$ -galactosidase by the transformed organisms grown on glucose and fructose as well as substantial quantities of  $\beta$ -galactosidase produced by glycerol and galactose grown cells was observed. Thus, the regulatory regions of the invention are capable of controlling the production of protein products in genetically very

diverse yeast hosts and are not limited to utilization in methanol utilizing strains.

EXAMPLES

5       The buffers and solutions employed in the following examples have the compositions given below:

1M Tris buffer       121.1 g Tris base in 800 mL of H<sub>2</sub>O;  
10                   adjust pH to the desired value by  
                  adding concentrated (35%) aqueous HCl;  
                  allow solution to cool to room  
                  temperature before final pH adjustment,  
15                   dilute to a final volume of 1L.

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5	S-buffer	1.5 <u>M</u> sorbitol in 0.04 <u>M</u> sodium phosphate buffer at pH 6.6.
10	PK buffer	0.14 <u>M</u> NaCl 1% Sodium dodecylsulfate (SDS) 0.01 <u>M</u> EDTA in 0.05 <u>M</u> (pH 8.4) Tris buffer
15	ETS buffer	10m <u>M</u> EDTA 0.2 % SDS in 0.01 <u>M</u> (pH 7.4) Tris buffer
20	TE buffer	1.0 m <u>M</u> EDTA in 0.01 <u>M</u> (pH 7.4) Tris buffer
25	SSC	0.15 <u>M</u> NaCl 15 m <u>M</u> sodium citrate adjusted to pH 7.0 with NaOH
30	TAE	40 m <u>M</u> acetic acid 5 m <u>M</u> EDTA in 0.02 <u>M</u> (pH 8.3) Tris buffer
35	PBS (Phosphate buffered saline)	10 m <u>M</u> sodium phosphate (pH 7.0) 0.15 <u>M</u> NaCl
40	Laemmli Loading Buffer	62.5 m <u>M</u> Tris-HCl (pH 6.8) 2% SDS 10% glycerol 5% 2-mercaptoethanol 0.01% bromphenol blue
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50		
55		

<p>5</p> <p>10</p> <p>15</p> <p>20</p> <p>25</p> <p>30</p> <p>35</p> <p>40</p> <p>45</p> <p>50</p> <p>55</p>	<p>RIPA Buffer</p> <p>20xSSPE</p> <p>Denhardts' Solution (50x)</p> <p>Prehybridization buffer</p> <p>LB (Luria-Bertani) Medium</p>	<p>1% NP40 (Sigma)</p> <p>1% sodium deoxycholate</p> <p>0.1% SDS</p> <p>in PBS</p> <p>20 mM EDTA</p> <p>0.16 M NaOH</p> <p>0.2 M <math>\text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}</math></p> <p>3.6 M NaCl</p> <p>adjusted pH to 7.0 with NaOH</p> <p>5 g Ficoll</p> <p>5 g polyvinylpyrrolidone</p> <p>5 g Bovine serum albumin (BSA; Pentax Fraction V)</p> <p>brought to a total volume of 500 mL with water</p> <p>5x SSPE</p> <p>5x Denhardt's solution</p> <p>50% deionized formamide</p> <p>0.2% SDS</p> <p>200 µg/mL sheared and denatured herring sperm DNA</p> <p>5 g Bacto-tryptone</p> <p>5 g Bacto-yeast extract</p> <p>2.5 g NaCl</p> <p>in 1 L of water, adjusted to pH 7.5 with NaOH</p>
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5	YPD Medium	1% Bacto-yeast extract 2% Bacto-peptone 2% Dextrose
10	SD Medium	6.75 g yeast nitrogen base without amino acids (DIFCO) 2% Dextrose in 1 L of water
15	SED	1 <u>M</u> Sorbitol 25 <u>mM</u> EDTA 50 <u>mM</u> DTT
20	SCE Buffer	9.1 g Sorbitol 1.47 g Sodium citrate 0.168 g EDTA 50 mL H <sub>2</sub> O --pH to 5.8 with HCl
25	CaS	1 <u>M</u> Sorbitol 10 <u>mM</u> CaCl <sub>2</sub> --filter sterilize
30	PEG Solution	20% polyethylene glycol-3350 10 <u>mM</u> CaCl <sub>2</sub> 10 <u>mM</u> Tris-HCl (pH 7.4) --filter sterilize
35		
40	SOS	1 <u>M</u> Sorbitol 0.3x YPD medium 10 <u>mM</u> CaCl <sub>2</sub>
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5	Formamide dy mix	0.1% xylene cyanol FF 0.2% bromphenol blue 10 mM EDTA 95% deionized formamide
10	Top gel	76.8 gm urea 24 mL acrylamide stock 8 mL 10x TBE bring to final volume of 160 mL
15	Acrylamide stock	38 gm acrylamide 2 gm bis(N,N-methylenebisacrylamide) add water to total volume of 100 mL
20	Bottom gel	14.4 gm urea 3.0 gm sucrose 7.5 mL 10x TBE 4.5 mL acrylamide stock 0.3 mL bromphenol blue solution (0.01 g/mL) add water to give total volume of 30 mL
25		
30	Prehybridization Buffer for hybridization selection	50% formamide 0.75 M NaCl 0.1 M Tris, pH 7.4 0.008 M EDTA 0.5% SDS 200 µg/mL rabbit liver tRNAs (Sigma)
35		
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**0.5 M NETS**

	Buffer	0.5 M NaCl
5		10 mM EDTA
		10 mM Tris, pH 7.4
		0.2% SDS
10	10X RT Buffer	500 mM NaCl
		340 mM Tris, pH 8.3
		60 mM MgCl <sub>2</sub>
15		50 mM DTT (dithiothreitol)
	dil RT	4 µL H <sub>2</sub> O
		1 µL 10X RT Buffer
20		5 µL reverse transcriptase, 15 U/µL (Life Sciences, Inc.)
25	dideoxy:	
	dd ATP	0.49 mM
	dd CTP	0.1165 mM
	dd GTP	0.369 mM
30	dd TTP	0.82 mM
	dNTP mix	0.625 mM dGTP
35		0.625 mM dATP
		0.625 mM TTP
40	Chase	1.125 mM dATP
		1.125 mM dCTP
		1.125 mM dGTP
		1.125 mM TTP
45		in 1X RT buffer

Unless otherwise specified, the above solutions represent the basic (1x) concentration employed. Throughout the examples, where the different concentration levels are employed, that fact is indicated by referring to the solution as a multiple of the basic (1x) concentration.

The following abbreviations are used throughout the examples, with the following meaning:

50	EDTA	ethylenediamine tetraacetic acid
	TEMED	N,N,N',N'-tetramethylethylenediamine
	DTT	dithiothreitol
	BSA	bovine serum albumin
55	EtBr	ethidium bromide
	Ci	Curie
	dATP	deoxyadenosine triphosphate
	dGTP	deoxyguanosine triphosphate

TTP	thymidine triphosphate
dCTP	deoxycytidine triphosphate
dXTP	"generic" deoxy triphosphate nucleotide
oligo(dT) <sub>12-18</sub>	Source: Collaborative Research, Inc.
5 Zymolyase 60,000	Source: Miles Laboratories

Several procedures carried out on a routine basis follow a standard protocol which will be detailed here.

Centrifugation is carried out for a period of time and at a spin rate sufficient to provide a clear supernatant. Generally, centrifugation of yeast cells is carried out at at least 1500 g for at least 5 minutes.

Nucleic acid extractions with phenol/chloroform/isoamyl alcohol involve contacting the nucleic acid  
10 containing solution with an equal volume of a 50:48:2 ratio by volume mixture of phenol, chloroform and isoamyl alcohol, respectively. Extractions with chloroform/isoamyl alcohol involve contacting the solution to be treated with an equal volume of 48:2 ratio by volume mixture of chloroform and isoamyl alcohol.

When gels, filters, etc. are described as being washed or soaked in a specified solution, the entire gel,  
15 filter, or the like was immersed in an appropriate vessel (pan, dish, vial, etc.) in order to contact the entire surface of the gel, filter, or the like with the solution of interest.

Ethanol precipitation of nucleic acids involves first adjusting the salt content of the nucleic acid-containing solution, then contacting the solution with two volumes of cold ethanol.

#### EXAMPLE I

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##### Growth and Preparation of Yeast Cells

*Pichia pastoris* NRRL Y-11430 was grown under carbon limited conditions in continuous culture at 30 °C with either methanol or ethanol as sole carbon source in IMI salts minimal medium as described by  
25 Wegner in U.S. 4,414,329. IM1 minimal media contains, per liter of media, 36 mM KH<sub>2</sub>PO<sub>4</sub>, 23mM (NH<sub>4</sub>)-<sub>2</sub>SO<sub>4</sub>, 2mM MgSO<sub>4</sub>, 6.7 mM KCl, 0.7 mM CaCl<sub>2</sub>, 0.2 μM CuSO<sub>4</sub> · 5 H<sub>2</sub>O, 1.25 μM KI, 4.5 μM MnSO<sub>4</sub>, 2 μM Na<sub>2</sub>MoO<sub>4</sub>, 0.75 μM H<sub>3</sub>BO<sub>3</sub>, 17.5 μM ZnSO<sub>4</sub>, 44.5 μM FeCl<sub>2</sub> and 1.6 μM biotin. The cells grown on methanol were grown up to a cell density of 140 g/L (dry weight) with a retention time of about 12 hours. The cells grown on ethanol were grown up to a cell density of 90 g/L with a retention time of about 11.5  
30 hours. When methanol or ethanol were fed into the fermenter, feed stocks containing concentrations of 20% and 45% alcohol, respectively, were used.

Ten grams of fermenter grown *Pichia pastoris* cells were collected by centrifugation and resuspended at approximately 10<sup>8</sup> cells/mL in 0.1 M Tris (pH 8.0) containing 1% 2-mercaptoethanol. These cells were incubated for 5 to 10 minutes at 37 °C and collected by centrifugation. The pellet was washed once with 30  
35 mL of S-buffer and resuspended in 5 mL of S-buffer per gram of cells. Zymolyase (Miles Biochemicals) was added to the cell suspension to give a final concentration of 500 μg/mL. The cells were incubated at 37 °C for 20 minutes and then centrifuged; supernatant discarded and the cell pellet collected. This pellet was frozen in liquid nitrogen and stored at -70 °C for later use.

#### 40 EXAMPLE II

##### Isolation of Yeast RNA

Total cell RNA was prepared by pulverizing the frozen pellet prepared as described in Example I with a  
45 mortar and pestle and further disrupting the frozen pellet for about 2-5 minutes in a Waring Blender in the presence of liquid nitrogen. The pulverized pellet was added to PK buffer at a concentration of 7.5 mL per gram of cells. Proteinase K (Boehringer Mannheim) was added to the resuspended pellet to give a final concentration of 400 μg/mL, and the suspension was incubated at room temperature for 10 minutes. This mixture was extracted with phenol/chloroform/isoamyl alcohol followed by a chloroform/isoamyl alcohol  
50 extraction. Nucleic acids were precipitated by adjusting the solution to be 0.25 M NaCl and adding ethanol. The pellet was resuspended in a minimum volume of ETS buffer, i.e. that volume of buffer sufficient to dissolve the nucleic acids; generally, about 100 μg up to about 1 mg of DNA per mL of solution. This solution was re-extracted with phenol/chloroform/isoamyl alcohol, then chloroform/isoamyl alcohol and finally precipitated with ethanol.

55 The nucleic acids were redissolved in a minimum volume of TE buffer. The RNA present in this solution was enriched either by centrifugation through a 4 mL CsCl cushion (1 g CsCl/mL, 1 mM EDTA, in 10 mM Tris (pH 7.4) buffer), or by precipitation by making the solution 2 M LiCl, maintaining at 4-8 °C overnight and collected by centrifugation. The poly A<sup>+</sup> RNA was selected from the solution by affinity chromatog-

raphy on oligo(dT)cellulose columns. Generally, 0.25 g of oligo (dT) cellulose, typ 3 (Collaborative Research) was prepared for chromatography per 5 to 10 mg of total RNA. 0.25 g of oligo (dT) cellulose was slurried in 2 mL of ETS buffer and poured into a small, siliconized glass column. This oligo (dT) cellulose column was washed by layering 10 mL of 0.1 M NaOH over the oligo (dT) cellulose and allowing the wash solution to flow through the oligo (dT) cellulose matrix. The oligo (dT) cellulose was then washed in the same manner with 10 mL of ETS buffer and washed a final time with 10 mL of 0.5 M NETS buffer.

Total RNA (5 to 10 mg) was resuspended in ETS buffer at a concentration not greater than about 10 mg/mL, placed in a 65°C water bath for 2 minutes and then placed immediately on ice. The RNA solution was then allowed to warm to room temperature and a stock solution of 5 M NaCl was added to give a final salt concentration in the RNA solution of 0.5 M NaCl. The resulting RNA solution was layered onto the prepared oligo (dT) cellulose column and allowed to slowly flow through the column at a rate of about 1 drop/5 seconds. The material flowing out the column bottom was collected in a tube and relayered onto the top of the column. The material collected from the column bottom was relayered on top a second time, resulting in the RNA solution being passed through the oligo (dT) cellulose column a total of three times. After the last pass through the column, the material was collected and labelled as the poly A-, i.e., non-poly A RNA. The column was then washed with 30 mL of 0.5 M NETS and finally the poly A+ RNA was eluted from the column by loading 5 mL of ETS buffer onto the column and allowing this buffer to flow through slowly, collecting the poly A+ RNA fraction in the 5 mL fraction flowing from the bottom of the column. Assuming that there was no NaCl in the poly A+ RNA fraction, the NaCl concentration of this fraction was adjusted to 0.25 M NaCl and RNA precipitated with ethanol.

### EXAMPLE III

#### Construction of cDNA Library

Complementary DNA (cDNA) clones were synthesized as follows. Ten µg of poly A+ RNA prepared as described in Example II was resuspended in 7 µL H<sub>2</sub>O and brought to a final concentration of 2.7 mM CH<sub>3</sub>HgOH, then incubated at room temperature for 5 minutes. The first strand of cDNA was synthesized at 42°C for 15 minutes in 50 µL of a solution containing 50 mM Tris, (pH 8.3 at 42°C), 10 mM MgCl<sub>2</sub>, 30 mM 2-mercaptoethanol, 70 mM KCl, 500 µM each of dATP, dGTP, and TTP, 200 µM dCTP, 25 µg/mL oligo(dT), 60 µg/mL actinomycin D, 25 units RNasin (Biotec, Inc.), 25 µCi α-<sup>32</sup>P dCTP (32.5 pmoles), and 120 units of reverse transcriptase (Life Sciences Inc.). This reaction mix was incubated at 37°C for an additional 15 minutes. The reaction was terminated by the addition of 2 µL of 0.5 M EDTA and 0.5 µL 20% SDS. The reaction was adjusted to 0.3 M NaOH and incubated at 65°C for 30 minutes. The reaction mix was then neutralized by the addition of 10 µL of 1 M Tris, (pH 7.4) and adjusting the reaction mix to 0.21 M HCl. The reaction mix was phenol/chloroform/isoamyl alcohol extracted, then chloroform/isoamyl alcohol extracted and finally chromatographed over a Sephadex G50 column in TE buffer. The radioactive single-stranded cDNA was pooled into one fraction and concentrated to 100 µL either by butanol extraction or evaporation by centrifugation under vacuum. The single stranded cDNA was ethanol precipitated from the concentrated solution, cDNA collected by centrifugation and resuspended in 100 µL of water.

The aqueous single-stranded cDNA solution was adjusted to 2.5 M ammonium acetate, ethanol precipitated, collected by centrifugation and resuspended in 20 µL of water. This single stranded DNA solution was brought to a final volume of 50 µL with 50 mM potassium phosphate buffer (pH 7.4) containing 5 mM MgCl<sub>2</sub>, 1 mM 2-mercaptoethanol, 250 µM each of dATP, dGTP, and TTP, 125 µM dCTP, 25 µCi-α-<sup>32</sup>P-dCTP (32.5 pmoles), and 8 units of Klenow fragment DNA Pol (New England Biolabs). The resulting reaction mixture was incubated at 37° for one hour in order to synthesize the complementary second DNA strand to the single stranded cDNA. The reaction was terminated by the addition of 2 µL of 0.5 M EDTA. The double stranded cDNA was phenol/chloroform/isoamyl alcohol extracted, chloroform/isoamyl alcohol extracted and chromatographed over a Sephadex G50 column in TE buffer. The double stranded cDNA fractions were pooled and the pool was concentrated and precipitated as described for the single-stranded cDNA.

After the final ethanol precipitation and the collection of the double stranded cDNA by centrifugation, the pellet was resuspended in 20.25 µL of water, then brought to a final volume of 50 µL with 50 mM Tris, (pH 8.3 at 42°C), containing 10 mM MgCl<sub>2</sub>, 30 mM 2-mercaptoethanol, 70 mM KCl, 500 µM of dATP, and 150 units of reverse transcriptase. The resulting solution was incubated at 42°C for 15 minutes in order to insure completion of the synthesis of the second strand of cDNA. The reaction was terminated by the addition of 2 µL of 0.5 M EDTA and concentrated and precipitated as described for the single stranded cDNA reaction.

The double stranded cDNA pellet was resuspended in 42  $\mu$ L of H<sub>2</sub>O and the solution brought to a final volume of 47  $\mu$ L by the addition of 5  $\mu$ L of a stock solution containing 2.8 M NaCl, 200 mM NaOAc and 45 mM ZnSO<sub>4</sub>, then adjusted to a pH of 4.5 at 22° C with HCl. In order to digest the hairpin loop, three separate reactions were done with three different concentrations of S<sub>1</sub> nuclease (Sigma). One unit, 10 units or 100 units of S<sub>1</sub> nuclease were added to bring the reaction volume to 50  $\mu$ L, and the reaction incubated at 22° C for 30 minutes. The reaction was terminated by the addition of 2  $\mu$ L of 0.5 M EDTA and 2.67  $\mu$ L of 2 M Tris base. Six  $\mu$ g of rabbit liver tRNA were added as a carrier, and the reaction mixture was concentrated and precipitated as described above except the DNA pellets were resuspended in TE buffer rather than water. After the final precipitation, the pellet was resuspended in 20  $\mu$ L of TE buffer and brought to a final volume of 50  $\mu$ L in terminal transferase buffer (BRL) containing 10 pmoles of  $\alpha$ -<sup>32</sup>P-dCTP, 2  $\mu$ M dCTP and 21 units of terminal transferase (Ratlift Biochem). The resulting solution was incubated at 37° C for 30 minutes in order to add poly d(C) tail to the 3'-OH end of the double-stranded cDNA. The reaction was terminated by the addition of 5  $\mu$ L of 0.5 M EDTA, extracted, chromatographed, and stored as an ethanol precipitate.

The double stranded, d(C) tailed cDNA was either reannealed directly to poly d(G) tailed pBR322 opened at the *Pst*I site or first size fractionated on a Sepharose CL4B-200 column (25  $\mu$ L fractions). For the unfractionated library, 150 ng of double-stranded poly d(C) tailed cDNA were annealed in 180  $\mu$ L of 10 mM Tris, (pH 7.4) which is 0.1 M in NaCl and 1 mM in EDTA to 900 ng of d(G) tailed pBR322 opened at the *Pst*I site. Each 25  $\mu$ L fraction of the fractionated library was annealed to 125 ng of poly d(G) tailed pBR322 in a 50  $\mu$ L final volume of the same annealing mixture described above. The annealing reactions were incubated at 65° C for 3 minutes, then 42° C for 2 hours and allowed to cool slowly to room temperature.

The annealed cDNA library was transformed into competent *E. coli* LE392 (ATCC 33572) prepared as follows: An inoculum of LE392 was grown overnight at 37° C in 2x LB media. Five mL of this overnight culture was inoculated into 200 mL of fresh 2x LB media and grown to an OD<sub>550</sub> of 0.2-0.3 at 37° C. This culture was placed on ice for 10 minutes and the cells were then collected by centrifugation at 4° C. The cell pellet was resuspended in 80 mL of ice cold 0.1 M CaCl<sub>2</sub> and incubated for 25 minutes at 4° C. The cells were collected by centrifugation at 4° C, the cell pellet resuspended in 2 mL of ice cold 0.1 M CaCl<sub>2</sub> and incubated for at least 2 hours at 4° C prior to use. Then 200  $\mu$ L of competent cells per 50  $\mu$ L of annealing mix were used for the transformation. The competent cells and the DNA were combined and incubated at about 4° C for ten minutes, followed by an incubation at 37° C for 5 minutes and finally placed on ice for 10 minutes. An equal volume of 2X LB media was added to the transformation mix and incubated at 37° C for 45 minutes. The transformed cells were plated at 250  $\mu$ L/plate on 150 mm 2x LB plates containing 15  $\mu$ g/mL of tetracycline. The plates were incubated at 37° C for 24 hours and stored at 4° C.

Replica filters were prepared by stamping nitrocellulose filters onto an original filter used to lift the colonies off of the plate. These replica filters were incubated on 2x LB-Tet (15  $\mu$ g/mL of tetracycline) plates. The colonies on the filters were prepared for probing by transferring the filters to 2x LB-Tet plates containing 200  $\mu$ g/mL of chloramphenicol, incubating the filters at 37° C for at least 12 hours, then lysing the colonies by floating the filters on an aqueous pool which is 1.5 M NaCl and 0.5 M NaOH for 10 minutes. The filters were then neutralized by floating them on an aqueous pool which is 1.5 M NaCl and 0.5 M Tris, (pH 7.4) for 15 minutes and repeating this neutralization again. The filters were then air dried and finally dried under vacuum for 2 hours at 70° C.

#### EXAMPLE IV

##### Colony Hybridization

The vacuum dried nitrocellulose filters containing the cDNA library (prepared as described in the previous example) were prehybridized at 42° C. for 5 hours in prehybridization buffer. The filters were removed from the prehybridization buffer and lightly rubbed with a gloved hand in 5x SSPE in order to remove cell debris. The filters were placed in hybridization buffer (same as prehybridization buffer except 1x Denhardt's). Either <sup>32</sup>P-labelled single-strand cDNA (10<sup>6</sup> cpm/mL) or end-labeled poly A+ RNA was hybridized to the filters for 17 hours at 42° C. After hybridization, the filters were washed briefly in 2x SSPE at 22° C, followed by two washes at 65° C in 0.1x SSPE, 10 minutes each.

End-labeling of poly A+ mRNA was performed by adding 2  $\mu$ g of poly A+ mRNA to a volume of 50  $\mu$ L containing 50mM Tris, (pH 9.5) heating to 100° C for three minutes, and rapidly chilling on ice. This RNA solution was diluted to a final volume of 200  $\mu$ L and adjusted to 50 mM Tris, (pH 9.5) 10 mM MgCl<sub>2</sub>, 5mM DTT and 50 pmoles of <sup>32</sup>P- $\alpha$ -ATP. Ten units of T<sub>4</sub> polynucleotide kinase (Boehringer Mannheim) was added and the mixture incubated at 37° C for one hour. The kinasing reaction was terminated by the addition of 10

$\mu$ L of 0.5 M EDTA, extracted with phenol/chloroform/isoamyl alcohol and chromatographed through Sephadex G50 to remove the unincorporated radioactive label.

#### EXAMPLE V

##### Northern Hybridizations

Two to five  $\mu$ g of poly A<sup>+</sup> mRNA were heated at 65°C for 5 minutes in 10 mM sodium phosphate buffer (pH 7.4) containing 50% formamide, 2.2 M formaldehyde, and 0.5 mM EDTA. The resulting solution was cooled to room temperature and an appropriate amount (generally about 0.2 volumes based on the volume of sample treated) of 5x sample buffer (0.5% SDS, 0.025% bromophenol blue, 25% glycerol, 25 mM EDTA) was added. The samples were loaded on a 1.5% agarose gel prepared in 10 mM sodium phosphate buffer (pH 7.4), containing 1.1 M formaldehyde, and electrophoresed in the same buffer. The gel was stained with acridine orange (33  $\mu$ g/mL) in 10 mM sodium phosphate buffer (pH 7.4), destained by soaking the gel in the same buffer for 10 minutes, soaked in 10x SSPE for at least 10 minutes, and the RNA transferred to nitrocellulose as described in Example VI.

#### EXAMPLE VI

##### Isolation Of Genomic DNA And Clones

*Pichia* genomic DNA was isolated using the method described in Example II for *Pichia* RNA isolation. The nucleic acid pellet was resuspended in a minimum volume TE buffer, and incubated with 20  $\mu$ g/mL RNase A for 30 minutes at 37°C. The solution was brought to 0.14 M NaCl and treated with proteinase K at 200  $\mu$ g/mL for 15 minutes at 22°C. The resulting solution was first extracted with phenol/chloroform/isoamyl alcohol and then with chloroform/isoamyl alcohol and finally ethanol precipitated. The precipitated DNA was resuspended in a minimum volume of TE buffer, and centrifuged in order to clear the DNA solution.

Ten  $\mu$ g of *Pichia* genomic DNA prepared as described in the previous paragraph was digested with various restriction enzymes (BRL) and electrophoresed on a 1% agarose gel containing TAE. The DNA fragments in the gel were denatured by soaking the gel in 1.5 M NaCl, 0.5 M NaOH for 20 minutes. The gel was neutralized by soaking in 1.5 M NaCl, 0.5 M Tris, (pH 7.4) for 20 minutes. Prior to transfer, the gel was soaked in 10x SSPE for at least 5 minutes. A sheet of nitrocellulose was cut to the size of the gel, wetted in water and soaked briefly in 10x SSPE. This filter was laid on top of the gel which in turn had been placed on a piece of parafilm. A sheet of Whatman filter paper and a stack of paper towels were placed on top of the nitrocellulose in order to draw the DNA out of the gel and transfer it to the nitrocellulose. A weight was placed on the stack to facilitate transfer. The DNA was allowed to transfer in this manner for at least 3 hours. After the transfer, the filter was soaked in 5x SSPE briefly, air dried, and dried under vacuum at 70°C for 2 hours. Complementary genomic fragments were identified by hybridization to nick-translated cDNA clones pPC 8.0, pPC 6.4 and pPC 15.0 using the same prehybridization, hybridization, and washing buffers described in Example IV.

200 ng of the cDNA clones were nick-translated for 90 minutes at 14°C in 30  $\mu$ L of a solution containing 50 mM Tris-HCl (pH 7.4), 10 mM MgSO<sub>4</sub>, 100  $\mu$ M DTT, 50  $\mu$ g/mL BSA, 20  $\mu$ M each of dGTP, TTP and dATP, 31.25 pmoles <sup>32</sup>P- $\alpha$ -dCTP (3200 Ci/mmol, NEN), 2 units *E. coli* DNA Pol I (BRL), and 0.02 ng DNaseI. The reaction was terminated by the addition of 1  $\mu$ L of 0.5 M EDTA and 1  $\mu$ L of 20% SDS. The labelled DNA solution was brought to a final concentration of 0.3 M NaOH and placed in boiling water for 3 minutes. This mixture was chromatographed on a Sephadex G50 column. The labelled DNA fractions were pooled, the specific activity determined and the probe used in hybridization experiments.

Genomic fragments which hybridized to the cDNA probes were isolated by digesting 200  $\mu$ g of *Pichia* genomic DNA with various restriction enzymes (BRL) and electrophoresing the digest on a 1% agarose gel in TAE buffer. The appropriate sized band was sliced from the agarose gel, the DNA electroeluted, passed through an Elutip column (Schleicher and Schuell) and ethanol precipitated.

The electroeluted fragments were resuspended in water and 200 ng fragments were ligated to 500 ng of pBR322 which was cleaved at the appropriate restriction site and dephosphorylated when necessary. The ligation reaction was carried out in 300  $\mu$ L of 66 mM Tris, (pH 7.4) containing 6.6 mM MgCl<sub>2</sub>, 10 mM DTT, 0.4 mM ATP, 25  $\mu$ g/mL BSA, and 40-80 units of T4 DNA ligase, then incubated at 4°C for 24 hours. The ligation mix was transformed directly into competent LE392 *E. coli* cells. The cells were made competent and the transformation done as described in Example III. A series of three transformations were done with 10, 40, and 100 ng of pBR322 (plus insert), each transformation in 100  $\mu$ L of competent cells. The cells

were plated as described in Example III except the antibiotic selection was 50 µg/mL of ampicillin. The clones were transferred to nitrocellulose, replicated and prepared for hybridization as described in Example III. The filters were probed with the appropriate nick-translated cDNA fragment. Streak-purified colonies which were positive in the hybridization were used to prepare additional plasmid, as follows.

5 The plasmid bearing LE392 *E. coli* was grown to an OD<sub>500</sub> of 1.0 in 1x LB media containing 50 µg/mL of ampicillin and amplified overnight by the addition of chloramphenicol to a final concentration of 200 µg/mL. The cells were washed in 0.8% NaCl, 20 mM Tris, (pH 8.0) 20 mM EDTA, then lysosome treated in 25% sucrose, 50 mM Tris, (pH 7.4) and 20 mM EDTA with 450 µg/mL Lysozyme. Lysis was achieved by adding 5 M NaCl to a final concentration of 2.0 M followed by the addition of an equal volume of 0.2% Triton X-100 and 40 mM EDTA. The preparation was cleared by spinning at 20,000 RPM for 45 minutes. 10 The supernatant was then phenol/chloroform/isoamyl alcohol extracted, chloroform/isoamyl alcohol extracted and EtOH precipitated. The pellet was resuspended in TE buffer, RNase A treated, phenol/chloroform/isoamyl alcohol extracted and chloroform/isoamyl alcohol extracted. Solid CsCl was added to give a final concentration of 800 µg/mL plus EtBr was added to give a final concentration of 1 mg/mL. The resulting solution was spun in a Vti 50 rotor at 49,000 RPM for 18-20 hours at 20°C.

The plasmid band was visualized by UV fluorescence and drawn from the tube using a needle and syringe. The plasmid solution was n-butanol extracted four times and ethanol precipitated at -20°C. The ethanol precipitation was repeated at least twice to remove all of the CsCl. The plasmid was stored at -20°C as an ethanol precipitate.

## 20 EXAMPLE VII

### Purification Of Alcohol Oxidase

25 Protein samples from *Pichia pastoris* cells grown on methanol as described in Example I were prepared by lysis of yeast cells, followed by a clearing spin to remove cell debris, as follows: A portion of the fermenter effluent was removed and adjusted to pH 7.5 with ammonium hydroxide, and was homogenized on a Dyno-Mill Model KDL using a 0.6 liter vessel in a continuous operation at 30°C. using belt combination #3 and a flow of 20-30 mL/hr. The beads in the mill were lead free glass beads with a diameter of 0.3-0.5 mm. The resulting homogenate was centrifuged at 5°C. and 20,000Xg for 30 minutes to yield a cell-free supernatant.

30 Six 130 mL portions of the cell-free supernatant were placed in cellulose acetate dialysis bags and dialyzed at 5°C. against about 8 liters of distilled water. After 4 days, the aqueous phase of each bag was decanted. The solids remaining in the bags consisted of two types of solid. The thin upper white layer was carefully removed and discarded. The bottom solid was brown-yellow and was crystalline alcohol oxidase. A portion of the crystalline alcohol oxidase was dissolved in distilled water (about 10 times the volume of the solid) and an assay by the dye-peroxidase method showed an activity of 94 EU/mL. The specific activity of the alcohol oxidase was 10.4 EU/mg of protein.

35 The crystalline precipitate resulting from the above-described dialysis was dialyzed against 0.05 M potassium phosphate buffer (pH 7.5), and applied to a 2x 200 cm Sephacryl 200 (Pharmacia) column equilibrated with the same buffer. Fractions of 3.5 mL were collected at a flow rate of 10 mL/hr and assayed for alcohol oxidase activity.

40 The alcohol oxidase activity for reaction with methanol was determined by the following assay procedure (dye-peroxidase method). A dye-buffer mixture was prepared by mixing 0.1 mL of an o-dianisidine solution (1 weight % o-dianisidine in water) with 12 mL of aerated 0.1 M sodium phosphate buffer (pH 7.5). The assay mixture was prepared with 2.5 mL of the dye-buffer mixture, 50 µL of methanol, 10 µL of a peroxidase solution (1 mg of horse-radish peroxidase-Sigma, Type II), and 25 µL of the alcohol oxidase solution. The assay mixture was maintained at 25°C in a 4x1x1 cm cuvette and the increase in absorbance by the dye at 460 nm was recorded for 2 to 4 minutes. The enzyme activity was calculated by

$$50 \quad \text{Activity } (\mu \text{ mole/min/mL or Enzyme Units/mL}) = \frac{\Delta A}{\text{min}} \times 11.5$$

55 where 11.5 is a factor based on a standard curve prepared with known aliquots of H<sub>2</sub>O<sub>2</sub> and ΔA is the change in absorbance during the experimental interval.

A total of 0.1 µg of total protein from each fraction was also assayed for alcohol oxidase content by gel

electrophoresis with SDS-polyacrylamide (12%).

#### EXAMPLE VIII

##### 5 DNA And Protein Sequencing

Determination of DNA sequences was performed by the dideoxy chain elongation method using bacteriophage M13 (Sanger et al, 1980) or by the chemical modification method (Maxam and Gilbert, 1980). The DNA fragments corresponding to the 5' end of the alcohol oxidase gene were inserted into the M13mp8 and M13mp9 vectors or end-labelled for the chemical modification method using restriction enzyme sites available in this region.

The 710bp *HindIII/SalI* fragment from pPG 4.0 was end-labelled for Maxam-Gilbert sequencing by first digesting 33 µg of the plasmid with *HindIII*. The reaction mixture was phenol/chloroform/isoamyl alcohol extracted, chloroform/isoamyl alcohol extracted and ethanol precipitated. The DNA was collected by centrifugation and resuspended in 31 µL of water. 100 µCi of <sup>32</sup>P-α-dCTP (3200 Ci/mmol) and 2 units of Klenow fragment DNA *Poll* was added to the reaction mixture to give a final volume of 50 µL containing 400 µM dATP, 400 µM dGTP, 50 mM Tris, (pH 7.4), 10 mM MgSO<sub>4</sub>, and 1 mM DTT. The reaction mixture was incubated at 37°C for 1 hour and stopped by the addition of 2 µL of 0.5 M EDTA. The mixture was then phenol/chloroform/isoamyl alcohol extracted, chloroform/isoamyl alcohol extracted, chromatographed on a Sephadex G-50 column, and the labelled nucleic acid fractions pooled and ethanol precipitated. After centrifugation, the DNA pellet was resuspended in water and digested with *SalI*. The digest was electrophoresed on a 1% agarose gel in TAE buffer, and the 710 bp band was cut from the gel, the DNA electroeluted, butanol extracted, and ethanol precipitated. The fragment was resuspended in 100 µL of TE buffer, adjusted to 2.5 M ammonium acetate and then ethanol precipitated. The resulting DNA fragment was resuspended in TE buffer at a concentration of 50,000 cpm/µL.

The four base modification reactions were performed as follows: (a) the G (guanine) reaction was incubated for 8 minutes at 22°C and contained 1 µL (50,000 cpm) of the labelled DNA fragment, 4 µL of water, 200 µL of 50 mM sodium cacodylate, pH 8.0, 1 mM EDTA (DMS buffer) and 1 µL dimethyl sulfate. The reaction was terminated by the addition of 50 µL of DMS stop buffer containing 1.5 M sodium acetate, (pH 7.0), 1 M 2-mercaptoethanol and 100 µg/mL tRNA, then ethanol (750 µL) was added and the reaction mixture was held at -70°C for at least 15 minutes. (b) the G/A (guanine/adenine) reaction was incubated for 10 minutes at 22°C and contained 2 µL (100,000 cpm) of the labelled DNA fragment, 8 µL of water and 30 µL of formic acid. The reaction was terminated by the addition of 200 µL of Hz stop buffer (0.3 M sodium acetate, pH 5.5, 0.1 M EDTA and 25 µg/mL tRNA), then ethanol (750 µL) was added and the reaction mixture held at -70°C for at least 15 minutes. (c) the T/C (thymine/cytosine) reaction was incubated for 10 minutes at 22°C and contained 2 µL (100,000 cpm) of the labelled DNA fragment, 18 µL of water and 30 µL of hydrazine. The reaction was terminated as described in (b) above. (d) the C (cytosine) reaction was incubated for 10 minutes at 22°C and contained 1 µL (50,000 cpm) of the labelled DNA fragment, 4 µL of water, 15 µL of 5 M NaCl, and 30 µL of hydrazine. The reaction was terminated as described in (b) above.

The DNA pellets were collected by centrifugation, resuspended in 250 µL of 0.3 M sodium acetate, pH 5.5 and ethanol precipitated with 750 µL of 95% ethanol. The pellets were collected by centrifugation, dried under vacuum for 5 minutes, and the DNA cleaved by resuspending the pellets in 100 µL of a 1 to 10 (v/v) dilution of piperidine. The cleavage reaction was incubated at 90°C for 30 minutes and terminated by the addition of 500 µL of 98% ethanol, 60 mM sodium acetate (pH 5.5) and 10 µg/mL tRNA. The reaction mixture was placed in a dry-ice/ethanol bath (about -70°C) for about 5 minutes and the DNA fragments were collected by centrifugation. The fragments were resuspended in 50 µL of 0.3 M sodium acetate (pH 5.5) and then ethanol precipitated with 100 µL of 95% ethanol. This ethanol precipitation was repeated, the pellets were washed with 95% ethanol and evaporated under vacuum during centrifugation. The pellet was resuspended in 10 µL of 80% formamide, 10 mM NaOH, 1 mM EDTA, 0.1% xylene cyanol and 0.1% bromphenol blue. Two to three µL were electrophoresed on a 10% 0.4 mm thick polyacrylamide gel in TBE buffer.

The amino acid sequence of alcohol oxidase was determined by Sequemat, Inc. (Watertown, Mass.) using 2 mg of purified alcohol oxidase from *Pichia pastoris*. The first 18 amino acids of the mature protein were determined to be:

Ala-Ile-Pro-Glu-Glu-Phe-Asp-Ile-Leu-Val-Leu-Gly-Gly-Gly-Ser-Gly-Ser.

#### EXAMPLE IX

##### Determination Of Alcohol Oxidase Transcriptional Initiation Site

To determine where the start of the mRNA for alcohol oxidase was located, a primer extension experiment was performed using a synthetic oligonucleotide copied from the DNA sequences of the 5' end of the alcohol oxidase gene as primer and 10 µg of poly A+ *Pichia pastoris* mRNA as template. Ten µg of *Pichia pastoris* poly A+ mRNA was combined with 3 ng of primer (5'-CTT CTC AAG TTG TCG-3') in a final volume of 9.3 µL which was 43 mM NaCl, 29.2 mM Tris (pH 8.3), 5.2 mM MgCl<sub>2</sub> and 4.3 mM DTT. The nucleic acids were denatured at 70° C for 5 minutes and reannealed by allowing to slowly cool to 22° C. The reannealing mix was added to a tube containing 4 µL of dNTP mix, 0.8 µL RT buffer, and 1 µL <sup>32</sup>P-α-dCTP (800 Ci/mmol). Three µL of this mixture was added to 1 µL of each respective dNTP. The final 3 µL in the mixture was added to 1 µL of water. The reactions were started by the addition of 1 µL of dil RT and incubated at 42° C for 15 minutes. The reactions were chased with 3 µL of Chase RT at 42° C for 15 minutes. The reactions were stopped by the addition of 7.5 µL formamide dye mix and 4-5 µL were electrophoresed on a 0.4 mm thick gradient gel in 1x TBE. After electrophoresis the gel was fixed in 10% acetic acid with 10% methanol for 20 minutes. The gel was dried under vacuum and used to expose an XAR X-ray film.

The gradient gel was prepared as follows: 300 µL of 10% ammonium persulphate and 14 µL of TEMED were added to 30 mL of top gel; 75 µL of 10% ammonium persulfate and 3.5 µL TEMED were added to 7 mL of bottom gel, 6 mL of top gel were drawn up into a pipet and then 6 mL of bottom gel were drawn into the same pipet. The gel was poured between the gel plates followed by 22 mL of top gel.

#### EXAMPLE X

##### mRNA Hybridization-Selection And In Vitro Translations

Positive hybridization-translation experiments were performed by linearizing twenty µg of cloned *Pichia* genomic DNA (prepared as described in Example VI) by digestion with various restriction endonucleases. This DNA was denatured by making the solution 0.3 M NaOH and incubating at 65° C for 10 minutes. The denatured DNA-containing solution was quickly chilled on ice and neutralized by adjusting to 0.5 M Tris·HCl (pH 7.4). An equal volume of 20x SSPE was added to the denatured DNA immediately prior to binding the DNA to the nitrocellulose filters. Prior to applying the DNA to the nitrocellulose filters (Schleicher and Schuell BA83, 9 mm dia.), the filters were prepared by wetting with H<sub>2</sub>O, boiling for 10 minutes and rinsing three times in 10x SSPE. Ten µg of DNA was then bound to each filter by applying the DNA to the filter, air drying and finally drying the filters under vacuum at 70° C for 2 hours.

Prior to prehybridization, the filters with the bound DNA were placed in 1 mL of sterile water and heated for one minute at 100° C, cooled on ice, rinsed by vortexing in 1 mL of sterile water and rinsed with 1 mL of prehybridization buffer. The filters were prehybridized in 1 mL of prehybridization buffer, then 40 µg (2µg/mL ETS) of poly A+ mRNA was added directly to the prehybridization buffer. The hybridization mixture was heated at 65° C for 10 minutes and then incubated at 42° C for 24 hours.

Following the hybridization, filters were washed briefly 2 times in 1x SSPE which contained 0.5% SDS at 22° C, 7 times in 1x SSPE which contained 0.5% SDS at 50° C for 5 minutes each, 3 times in 0.1x SSPE at 50° C for 5 minutes each, and once in 0.1x SSPE at 65° C for 10 minutes. The RNA was eluted from the filters by boiling for 1 minute in 300 µL of H<sub>2</sub>O containing 15 µg of rabbit liver tRNA. The eluted RNA was quickly frozen in a dry-ice ethanol bath. The RNA mixture was allowed to warm to room temperature and the filters removed. The RNA mixture was then precipitated by adjusting the medium to 2.5 M ammonium acetate and precipitating with ethanol 2 times, and finally resuspended in 100 µL of H<sub>2</sub>O before being lyophilized.

Translations were performed according to standard techniques known by those of skill in the art, such as for example, instructions provided by New England Nuclear *in vitro* rabbit reticulocyte lysate translation kits. Protein products were electrophoresed on 8% polyacrylamide gels containing a 4.5% stacking gel.



EXAMPLE XIAntisera Preparations And Immunoprecipitations

5 Antisera raised in rabbits against an extract from *Pichia pastoris* cells containing both p72 (alcohol oxidase) and p76 polypeptides were prepared using standard protocols. Extracts were dialyzed against PBS before injections. Over a course of 8 weeks, each rabbit received 3 injections each of which consisted of 1 mg of total protein in a volume of 0.1 mL with 0.2 mL of Freund's complete adjuvant. Injections were intradermally delivered to 6-10 sites in the rabbit. At the end of eight weeks, the rabbits were bled, and their sera tested against purified *Pichia pastoris* alcohol oxidase by the Ouchterlony double diffusion procedure.

10 Purified rabbit anti-p72 (alcohol oxidase) and anti-p76 protein antibodies were prepared by affinity chromatography of whole antisera through a CNBr coupled p72 (alcohol oxidase)-p76 Sepharose 4B column (Pharmacia). One gram of CNBr activated gel was prepared by hydrating the gel for 15 minutes in 200 mL of 1 mM HCl followed by 3x 50 mL washes in coupling buffer (0.1 M sodium carbonate (pH 8) and 0.5 M NaCl). Five mL of a 6 mg/mL solution of p72-p76 in coupling buffer was added to the gel and gently agitated overnight at 4°C. Unbound protein was removed by washing 3x 50 mL with coupling buffer. The remaining active groups were eliminated by a 2-hour incubation in 1 M ethanolamine (pH 8). Non-covalently bound material was removed from the gel by a 50 mL wash with 2 M sodium thiocyanate in PBS. Prior to chromatography of the antisera, the gel was finally washed with 3x 50 mL of PBS. Five mL of clarified anti-p72-p76 antisera were mixed with the gel and incubated with gentle agitation for 2 hours at 4°C. The antisera-gel mixture was then pipetted into a 1x 8 cm column and washed with 150 mL of PBS. Purified antibody was eluted from the column with 6 mL of 2 M sodium thiocyanate in PBS. After elution from the gel, the purified antibody was dialyzed extensively against PBS which contained 0.02% sodium azide.

25 The affinity-purified antisera was added to an *in vitro* translation mix in PBS, 1% NP40 and incubated overnight at 4°C. The antibody-antigen complex was precipitated with Pansorbin (Calbiochem) on ice for 2.5 hours. Pansorbin was prepared by washing in RIPA buffer. Pansorbin precipitates were washed 4 times in RIPA buffer and dissolved in Laemmli loading buffer before electrophoresis.

EXAMPLE XII

30

*Pichia pastoris* Transformation ProcedureA. Cell Growth

- 35 1. Inoculate a colony of *Pichia pastoris* GS115 (NRRL Y-15851) into about 10 mL of YPD medium and shake culture at 30°C for 12-20 hrs.
2. After about 12-20 hrs., dilute cells to an OD<sub>600</sub> of about 0.01-0.1 and maintain cells in log growth phase in YPD medium at 30°C for about 6-8 hrs.
3. After about 6-8 hrs, inoculate 100 mL of YPD medium with 0.5 mL of the seed culture at an OD<sub>600</sub> of about 0.1 (or equivalent amount). Shake at 30°C for about 12-20 hrs.
- 40 4. Harvest culture when OD<sub>600</sub> is about 0.2-0.3 (after approximately 16-20 hrs) by centrifugation at 1500 g for 5 minutes.

B. Preparation of Spheroplasts

45

- 1 Wash cells once in 10 mL of sterile water. (All centrifugations for steps 1-5 are at 1500 g for 5 minutes.)
2. Wash cells once in 10 mL of freshly prepared SED.
3. Wash cells twice in 10 mL of sterile 1 M Sorbitol.
- 50 4. Resuspend cells in 10 mL SCE buffer.
5. Add 5-10 µL of 4 mg/mL Zymolyase 60,000 (Miles Laboratories). Incubate cells at 30°C for about 30-60 minutes.

55 Since the preparation of spheroplasts is a critical step in the transformation procedure, one should monitor spheroplast formation as follows: add 100 µL aliquots of cells to 900 µL of 5% SDS and 900 µL of 1 M Sorbitol before or just after the addition of zymolyase and at various times during the incubation period. Stop the incubation at the point where cells lyse in SDS but not in sorbitol (usually between 30 and 60 minutes of incubation).

6. Wash spheroplasts twice in 10 mL of sterile 1 M Sorbitol by centrifugation at 1000 g for 5-10 minutes.

(The time and speed for centrifugation may vary; centrifuge enough to pellet spheroplasts but not so much that they rupture from the force.)

7. Wash cells once in 10 mL of sterile CaS.

8. Resuspend cells in total of 0.6 mL of CaS.

### C. Transformation

1. Add DNA samples (up to 20  $\mu$ L volume) to 12 X 75 mm sterile polypropylene tubes. (DNA should be in water or TE buffer; for maximum transformation frequencies with small amounts of DNA, it is advisable to add about 1  $\mu$ L of 5 mg/mL sonicated *E. coli* DNA to each sample.)

2. Add 100  $\mu$ L of spheroplasts to each DNA sample and incubate at room temperature for about 20 minutes.

3. Add 1 mL of PEG solution to each sample and incubate at room temperature for about 15 minutes.

4. Centrifuge samples at 1000 g for 5-10 minutes and decant PEG solution.

5. Resuspend samples in 150  $\mu$ L of SOS and incubate for 30 minutes at room temperature.

6. Add 850  $\mu$ L of sterile 1 M Sorbitol and plate aliquots of samples as described below.

### D. Regeneration of Spheroplasts

1. Recipe for Regeneration Agar Medium:

a. Agar-Sorbitol- 9 g Bacto-agar, 54.6 g Sorbitol, 240 mL H<sub>2</sub>O, autoclave.

b. 10X Glucose- 20 g Dextrose, 100 mL H<sub>2</sub>O, autoclave.

c. 10X SC- 6.75 g Yeast Nitrogen Base without amino acids, 100 mL H<sub>2</sub>O, autoclave. (Add any desired amino acid or nucleic acid up to a concentration of 200  $\mu$ g/mL before or after autoclaving.)

d. Add 30 mL of 10X Glucose and 30 mL of 10X SC to 240 mL of the melted Agar-Sorbitol solution. Add 0.6 mL of 0.2 mg/mL biotin and any other desired amino acid or nucleic acid to a concentration of 20  $\mu$ g/mL. Hold melted Regeneration Agar at 55-60 °C.

2. Plating of Transformation Samples:

Pour bottom agar layer of 10 mL Regeneration Agar per plate at least 30 minutes before transformation samples are ready. Distribute 10 mL aliquots of Regeneration Agar to tubes in a 45-50 °C bath during the period that transformation samples are in SOS. Add aliquots of transformation samples described above to tubes with Regeneration Agar and pour onto bottom agar layer of plates. Add a quantity of each sample to 10 mL aliquots of melted Regeneration Agar held at 45-50 °C and pour each onto plates containing a solid 10 mL bottom agar layer of Regeneration Agar.

3. Determination of Quality of Spheroplast Preparation:

Remove 10  $\mu$ L of one sample and dilute 100 times by addition to 990  $\mu$ L of 1 M Sorbitol. Remove 10  $\mu$ L of the 100 fold dilution and dilute an additional 100 times by addition to a second 990  $\mu$ L aliquot of 1 M Sorbitol. Spread plate 100  $\mu$ L of both dilutions on YPD agar medium to determine the concentration of unspheroplasted whole cells remaining in the preparation. Add 100  $\mu$ L of each dilution to 10 mL of Regeneration Agar supplemented with 40  $\mu$ g/mL histidine to determine total regeneratable spheroplasts. Good values for a transformation experiment are 1-3 X 10<sup>7</sup> total regeneratable spheroplasts/mL and about 1 X 10<sup>3</sup> whole cells/mL.

4. Incubate plates at 30 °C for 3-5 days.

### Example XIII

#### Isolation Of *Pichia Pastoris* HIS4 Gene And Autonomous Replication Sequences

##### A. Strains

The strains employed include:

(a) *Pichia pastoris* strain NRRL Y-11430;

(b) *Pichia pastoris* GS115 (*his4*; NRRL Y-15851);

(c) *S. cerevisiae* strain 5799-4D (a *his4*-260 *his4*-39; NRRL Y-15859); and

(d) *E. coli* strain 848 (F<sup>-</sup> *met thi gal* T<sub>1</sub><sup>R</sup>  $\phi$ 80<sup>S</sup> *hsdR*<sup>-</sup> *hsdM*<sup>+</sup>).

##### B. Plasmids

pYA2 (see Figure 23; consists of the *S. cerevisiae* HIS4 gene on a 9.3 kbp *Pst*I fragment inserted at the *Pst*I site of pBR325) was the source of the *S. cerevisiae* HIS4 gene fragments and has been deposited in an *E. coli* host and is available to the public as NRRL B-15874.

YEpl3 is available from the American Type Culture Collection and has been assigned accession number ATCC 37115.

### C. Media

*Pichia pastoris* was grown in YPD (rich) or IMG (minimal) media. IMG, a minimal medium, consists of the following:

1. IM<sub>1</sub> Salts at a final concentration of 36.7 mM KH<sub>2</sub>PO<sub>4</sub>, 22.7 mM (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, 2.0 mM MgSO<sub>4</sub>·7H<sub>2</sub>O, 6.7 mM KCl, 0.7 mM CaCl<sub>2</sub>·2H<sub>2</sub>O, prepared as a 10x stock solution and autoclaved;
2. Trace Salts at a final concentration of 0.2 μM CuSO<sub>4</sub>·5H<sub>2</sub>O, 1.25 μM KI, 4.5 μM MnSO<sub>4</sub>·H<sub>2</sub>O, 2.0 μM NaMoO<sub>4</sub>·2H<sub>2</sub>O, 0.75 μM H<sub>3</sub>BO<sub>3</sub>, 17.5 μM ZnSO<sub>4</sub>·7H<sub>2</sub>O, 44.5 μM FeCl<sub>3</sub>·6H<sub>2</sub>O, prepared as a 400x stock solution and filter sterilized;
3. 0.4 μg/mL biotin; and
4. 2% dextrose.

*E. coli* was cultured in either LB medium or 2B medium (0.2% NH<sub>4</sub>PO<sub>4</sub>, 1.2% Na<sub>2</sub>HPO<sub>4</sub>, 0.013% MgSO<sub>4</sub>·7H<sub>2</sub>O, 0.074% CaCl<sub>2</sub>·2H<sub>2</sub>O, 1 μg/mL thiamine and 0.4% dextrose) supplemented with 100 μg/mL tryptophan, and 0.2% Casamino acids.

### D. DNA Isolation

#### 1. Large Scale Preparations of Yeast DNA.

Both *Pichia pastoris* and *S. cerevisiae* DNA preparations were carried out by growing yeast cells in 100 mL of minimal medium until A<sub>600</sub> equals 1-2 and then harvesting the cells by centrifugation at 2,000 g for 5 minutes. The cells were washed once in H<sub>2</sub>O, once in 1 M sorbitol and then suspended in 5 mL of 0.1 M Tris-HCl (pH 7.0) which is 1 M in sorbitol. The cells were mixed with 50-100 μL of a 4 mg/mL solution of Zymolase 60,000 (Miles Laboratories) and incubated at 30 °C for 1 hour to digest the cell walls. The spheroplast preparation was then centrifuged at 1000 g for 5-10 minutes and suspended in Lysis buffer (0.1% SDS, 10 mM Tris-HCl, (pH 7.4), 5 mM EDTA and 50 mM NaCl). Proteinase K (Boehringer Mannheim) and RNase A (Sigma) were each added to 100 μg/mL and the mixtures incubated at 37 °C for 30 minutes. DNA was deproteinized by gently mixing the preparation with an equal volume of chloroform containing isoamyl alcohol (24:1, v/v) and the phases were separated by centrifugation at 12,000 g for 20 minutes. The upper (aqueous) phase was drawn off into a fresh tube and extracted with an equal volume of phenol/chloroform/isoamyl alcohol. The phases were separated as before and the top phase placed in a tube containing 2-3 volumes of cold 100% ethanol. The sample was gently mixed and DNA was collected by spooling onto a plastic rod. The DNA was immediately dissolved in 1 mL of TE buffer and dialyzed overnight at 4 °C against 100 volumes TE buffer.

#### 2. Small Scale Yeast DNA Preparations.

Five mL of yeast cultures in minimal medium were grown until A<sub>600</sub> equals 1-5 and harvested by centrifugation at 2,000 g for 5 minutes. Cells were suspended in 1 mL of SED and transferred to a 1.5 mL microfuge tube, washed once in 1 M sorbitol and resuspended in 0.5 mL of 0.1 M Tris-HCl (pH 7.4) which is 1 M in sorbitol. Zymolase 60,000 (10 μL of a 4 mg/mL solution) was added and the cells were incubated for 30-60 minutes at 30 °C. Cells were then centrifuged for 1 minute, suspended in the Lysis buffer and incubated at 65-70 °C. After 15 minutes the samples were mixed with 100 μL of 5 M potassium acetate, held in an ice bath for 15 minutes and centrifuged for 5 minutes. The supernatants were decanted into a fresh microfuge tube containing 1 mL of 100% ethanol, mixed and centrifuged for 10 seconds. Finally, the DNA pellets were air dried for 10-15 minutes and dissolved in 50 μL of TE buffer.

#### 3. Large Scale *E. coli* DNA Isolations.

*E. coli* cultures for large scale (0.5-1 L) plasmid preparations were grown at 37 °C with shaking in 2B medium supplemented as described above and with the appropriate antibiotic. For cells which contained pBR322 derived plasmids, cultures were grown to an A<sub>550</sub> of about 0.7 at which time sufficient chloram-

phenicol was added to give a concentration of 100 µg/mL and cells harvested approximately 15 hours later. Strains which contained pBR325 derived plasmids were inoculated into the supplemented 2B medium at a starting  $A_{550}$  of about 0.01-0.05 and incubated with shaking at 37 °C for 20-24 hours before harvesting.

#### 5 4. Small Scale *E. coli* DNA Preparations.

For small scale rapid plasmid isolations, 2 mL cultures in the supplemented 2B medium with antibiotic were grown overnight at 37 °C with shaking and harvested by centrifugation in 1.5 mL microfuge tubes. Plasmids from all preparations were isolated by the alkaline lysis method described by Birnboim and Doly  
10 (1979).

#### E. Restriction DNA and Fragment Isolation.

Restriction enzymes were obtained from New England Biolabs and Bethesda Research Laboratories  
15 and digestions were performed by routine techniques. Restriction mappings were carried out by comparing parallel digestions of plasmids with and without insert DNA. Restriction fragments were purified by electroelution from agarose gels into Whatman 3 MM paper strips backed by dialysis tubing. The fragments were recovered from the paper and tubing by 3-4 washings with 0.1-0.2 mL volumes of a solution which contained 0.1 M NaCl, 50 mM Tris-HCl (pH 8.0) and 1 mM EDTA. Finally, the fragments were extracted with  
20 phenol/chloroform/isoamyl alcohol, precipitated with ethanol and redissolved in a small volume of TE buffer.

#### F. *P. pastoris* Library Construction in *E. Coll.*

For the *Pichia pastoris* DNA-YEpI3 library construction, 100 µg of YEpl3 was digested to completion  
25 with *Bam*HI and treated with calf intestinal alkaline phosphatase to remove the terminal 5' phosphate from the DNA. A 100 µg aliquot of wild type *Pichia pastoris* DNA from *Pichia pastoris* NRRL Y-11430 was partially digested with 10 units of *Sau*3A I by incubation for 5 minutes at 37 °C in a total volume of 1 mL. Fragments of 5 to 10 kbp were size selected by centrifugation through 5-20% sucrose gradients. One µg of the vector and 2 µg of the *Pichia Sau*3A I fragments were mixed with 20 units of T4 DNA ligase (Bethesda  
30 Research Laboratories) in a total volume of 200 µL and incubated overnight at 4 °C. The ligated DNAs were transformed into *E. coli* by adding the entire ligation reaction mix to 2 mL of competent *E. coli* 848 cells and incubating for 15 minutes at 0 °C. The mixture was warmed to 37 °C for 5 minutes after which time 40 mL of LB medium was added and the 37 °C incubation continued for another 1 hour. Ampicillin was then added to give a total concentration of 100 µg/mL and the incubation continued for a second hour. Finally,  
35 the cells were centrifuged for 10 minutes at 3,000 g, resuspended in 1 mL of fresh LB medium and spread in equal aliquots on 10 LB agar plates containing 100 µg/mL of ampicillin. The approximately 50,000 colonies which resulted were scraped from the plates and a portion of the cells was inoculated into 500 mL of the supplemented 2B medium at a starting  $A_{550}$  of about 0.1. The culture was grown and plasmid was extracted as described above. Of the colonies which were pooled for the library, 96 out of 100 tested were  
40 tetracycline sensitive and 7 out of 10 examined contained plasmids with insert DNA.

For the *Pichia pastoris* DNA-pYJ8Δ*Cla* library construction, 50 µg of pYJ8Δ*Cla* was digested to completion with *Cla*I and treated with calf intestinal alkaline phosphatase to remove the terminal 5' phosphate from the DNA. A 100 µg aliquot of DNA from *Pichia pastoris* NRRL Y-15851 was partially  
45 digested with 20 units of *Taq*I by incubation for 5 minutes at 65 °C in a total volume of 1 mL. Fragments of 5 to 10 kbp were size selected by electroelution from a 0.5% agarose gel (See Example II, Section E). One µg of the vector and 2 µg of the *Pichia Taq*I fragments were mixed with 20 units of T4 DNA ligase (Bethesda Research Laboratories) in a total volume of 200 µL and incubated overnight at 4 °C. The ligated DNAs were transformed into *E. coli* by adding the entire ligation reaction mix to 2 mL of competent *E. coli* 848 cells and incubating for 15 minutes at 0 °C. The mixture was warmed to 37 °C for 5 minutes after which  
50 time 40 mL of LB medium was added and the 37 °C incubation continued for another 1 hour. Ampicillin was then added to give a total concentration of 100 µg/mL and the incubation continued for a second hour. Finally, the cells were centrifuged for 10 minutes at 3,000 g, resuspended in 1 mL of fresh LB medium and spread in equal aliquots on 10 LB agar plates containing 100 µg/mL of ampicillin. The approximately 10,000 colonies which resulted were scraped from the plates and a portion of the cells was inoculated into 500 mL  
55 of the supplemented 2B medium at a starting  $A_{550}$  of about 0.1. The culture was grown and plasmid was extracted as described above.

#### G. Southern Hybridizations.

For transfer of large or supercoiled DNA molecules to nitrocellulose, DNA was first partially hydrolyzed by soaking agarose gels in 0.25 M HCl for 10 minutes prior to alkali denaturation. The hybridization of labelled fragments from the *S. cerevisiae* HIS4 gene to *Pichia pastoris* DNA was performed in the presence of 50% formamide, 6x SSC, 5x Denhardt's, 0.1% SDS, 1 mM EDTA, and 100 µg/mL denatured herring sperm DNA at 42°C. Post-hybridization washes were in 1x SSC, 1 mM EDTA, 0.1% SDS and 1.0% sodium pyrophosphate at 65°C. DNA was <sup>32</sup>P-labelled as described in Example IV.

#### H. DNA Sequencing.

DNA sequencing was by the dideoxynucleotide chain termination method of Sanger *et al* (1980).

#### I. Yeast Transformations

*S. cerevisiae* transformations were carried out by the spheroplast generation method of Hinnen *et al* (1978).

*Pichia pastoris* transformations were performed following the procedure described above.

#### J. Analysis of *Pichia pastoris* Transformants

The ability of each plasmid to be maintained as an autonomous element in *Pichia pastoris* cells was determined as follows: A transformant colony was picked from the regeneration agar plate and streaked onto an SD medium agar plate and inoculated into liquid IMG medium. The SD plate was incubated at 30°C for 3 days after which time a single colony was picked from this plate, streaked onto a second SD plate and inoculated into a second flask of IMG medium. This process was repeated a third time. The 3 IMG cultures were grown at 30°C with shaking to an A<sub>600</sub> of about 1-2 and then harvested by centrifugation. DNA from the yeast cultures was extracted as described above, electrophoresed at 30 Volts and 30 mAmps for 10-15 hours into 0.8% agarose gels, transferred to nitrocellulose and hybridized to <sup>32</sup>P-labelled pBR322 or pBR325 as described above. As controls, a sample containing 10 ng of plasmid isolated from *E. coli* and a sample containing 1-2 µg of untransformed *Pichia pastoris* GS115 DNA were electrophoresed in parallel with the experimental samples.

#### K. Isolation of *Pichia* DNA Sequences.

DNA fragments which contained the *Pichia* HIS4 gene were isolated from a *Pichia* DNA library by their ability to complement *S. cerevisiae* *his4* strains. The library was composed of 5-20 kbp *Sau3A*I partial digestion fragments of wild type *Pichia* DNA inserted into the *Bam*HI site of the *S. cerevisiae*-*E. coli* shuttle vector YEp13. Spheroplasts of *S. cerevisiae* NRRL Y-15859 (5799-4D; a *his4*ABC<sup>-</sup> strain) were generated by the technique of Hinnen *et al* (1978), mixed with the *Pichia* DNA library and allowed to regenerate in a medium deficient in histidine. The transformation resulted in about 1x10<sup>3</sup> prototrophic yeast colonies from a population of 5x10<sup>7</sup> total regeneratable spheroplasts. Total yeast DNA was extracted from 20 of the His<sup>+</sup> colonies and transformed into *E. coli*. Seventeen of the yeast DNA preparations produced ampicillin resistant colonies and each contained plasmid comprised of YEp13 plus insert DNA. To confirm that the His<sup>+</sup> transforming plasmids contained the *Pichia* HIS4 gene and not a DNA fragment with suppressor activity, restriction digests of the plasmids were hybridized to a labelled DNA fragment containing a large portion of the *S. cerevisiae* HIS4 gene and washed at low stringency. Each of the plasmids which complemented the *his4* *S. cerevisiae* strains contained sequences which hybridized to the *S. cerevisiae* HIS4 gene.

To search for DNA fragments which contain *Pichia* ARS activity, DNA from *Pichia pastoris* GS115 (NRRL Y-15851) was partially digested with *Taq*I and 5 to 10 kbp fragments were isolated and cloned into the unique *Cla*I site of pYJ8Δ*Cla*. (See Figure 26). Plasmid DNA was recovered from about 10,000 His<sup>+</sup> *Pichia* colonies and used to transform *E. coli*. Plasmids from about 10,000 ampicillin resistant colonies were isolated and then transformed back into GS115. Forty of the His<sup>+</sup> yeast colonies from this sublibrary transformation were separately streaked onto selective medium and grown in separate cultures in selective medium. Total yeast DNA was extracted from each of these 40 cultures and transformed into *E. coli*. Two plasmids, pYA63 (PARS1) and pYA90 (PARS2) whose yeast DNA preparations produced the most ampicillin resistant *E. coli* colonies, were selected for further analysis. Both of these plasmids transformed *Pichia pastoris* GS115 (NRRL Y-15851) at a very high frequency and each contained an insert of foreign DNA.

## EXAMPLE XIV

Construction Of Regulatory Region-*lacZ* Gene Fusions

## 5 A. p72 (Alcohol Oxidase) Regulatory Region Constructs

Plasmid pPG 4.0, a pBR322 vector which contains the 4 kilobase pair *EcoRI-PvuII* genomic DNA fragment from *Pichia pastoris* was cut with *PstI*, treated with S1 nuclease to produce blunt ends where cleavage occurred, then cut with *BamHI* to give a 1.12 kbp DNA fragment which contains the alcohol  
 10 oxidase regulatory region and the coding information for the first 15 amino acids of alcohol oxidase. This 1.12 kbp DNA fragment has the following nucleotide sequence:

15 "S<sub>1</sub> nuclease"..... 1.12 kbp  
 treated end .....CTA GGT GGT G  
 .....GAT CCA CCA CCT AG  
 20 alcohol oxidase leu<sub>11</sub> gly<sub>12</sub> gly<sub>13</sub>

B  
↓  
G  
CCT  
AG  
↑  
B

This 1.12 kbp was ligated into the *EcoRI/SmaI/BamHI* linker (cleaved with *BamHI* and *SmaI*) of the *E. coli*-*S. cerevisiae* shuttle vector pSEY101, Douglas *et al* (1984). Vector pSEY101 contains the *E. coli lacZ* gene  
 25 and a polylinker with the following nucleotide sequence:

30 .....GAATTCCCGGGGATCCC GTC GTT....  
 CTTAAGGCCCCCTAGGG CAG CAA....  
 R<sub>1</sub> Sm B  
 ↑ ↑ ↑  
 R<sub>1</sub> Sm B Val<sub>9</sub> Val<sub>10</sub>...β-galactosidase

35 to give hybrid plasmid pTA011 (See Figure 29).

Since the regulatory region-*lacZ* gene fusion of pTA011 is out of phase with respect to production of β-galactosidase as shown in Sequence E:

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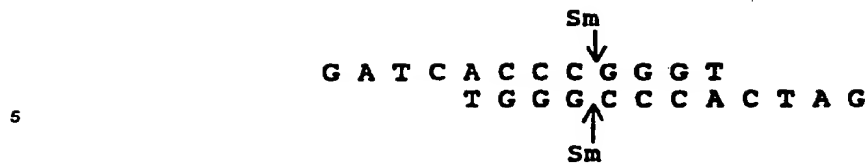
Sequence E

```

      ...GAATTCCC...1.12 kbp...CTA
      ...CTTAAGGG...GAT
      R1 ↓          ↑ R1
      ...GCT       GGT       GCT       TCC       CGT       T....
      ...CCA       CCA       CCA       AGG       GCA       A....
      ...          CCT       CCT       B
      leu11      gly12      gly13      gly14      arg      arg
  
```

Vector pTA011 is cleaved at the unique *Bam*HI site and the following *Sma*I linker inserted:

55



thus producing hybrid vector pTAO12, which has the following nucleotide sequence with respect to the  
 10 regulatory region-*lacZ* fusion:

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[illegible]

and thus, the regulatory region-*lacZ* fusion of pTAO12 is still out of phase with respect to the LacZ reading  
55 frame. In order to bring the N-terminal coding information for the alcohol oxidase structural gene into an  
open reading frame with the structural *lacZ* gene, pTAO12 was treated with *EcoRI-SmaI* and the resulting  
DNA fragment ligated into pSEY101 which had similarly been treated with *EcoRI* and *SmaI* thus producing  
hybrid vector pTAO13 (See Figure 30 and the nucleotide sequence below:



5 and pSAOH 10.

pTA013 plus	Resulting Plasmids
pTAFH1 pYJ30 pYA2	pSAOH1 pSAOH5 pSAOH10

#### B. p76 Regulatory Region Constructs

Regulatory region - *lacZ* gene fusions were prepared as follows with the p76 regulatory region.

##### 1. Using the Entire 5' Portion of pPG 6.0

The 1.35 kbp *EcoRI* fragment of pPG 6.0 was cloned into the unique *EcoRI* site of pSEY101, an *E. coli*-*S. cerevisiae* shuttle vector, giving plasmid pT76U1 (see Figure 30a). Vector pT76U1 was then cleaved with *PstI*-*NruI*, and the larger DNA fragment ligated with the *HIS4* gene-containing fragment of shuttle vector pTAFH1 (Figure 28) as described above to give pT76H3; or with the *EcoRI*-end filled in *PstI*-*EcoRI* fragment of shuttle vector pBPf1 (see Figure 34) to give pT76H4.

##### 2. Using a *Bal31* Digest of 5'-pPG 6.0

A 1.35 kb pair *EcoRI* fragment of pPG 6.0 was cloned into the unique *EcoRI* site of pSEY8, an *E. coli*-*S. cerevisiae* shuttle vector, which also has a unique *SalI* site adjacent to the *EcoRI* site into which the *Pichia* DNA was inserted, thus giving plasmid pTA01 (See Figure 31). The plasmid pTA01 was cleaved with *SalI*, treated with *Bal31* exonuclease to produce blunt-ended fragments of polypeptide p76 regulatory region of various lengths. The blunt-ended fragments were freed from the remainder of plasmid pSEY8 by cleavage with *EcoRI*. The resulting DNA fragments were cloned into the *EcoRI*-*SmaI* linker of pSEY101 to give, among others, plasmid pTAF.85 (see Figure 32). Plasmid pTAF.85 is analogous to pTA011 shown in Figure 29, with the p76 regulatory region instead of the p72 (alcohol oxidase) regulatory region.

Vector pTAF.85 was then treated in an analogous fashion as vector pTA013 to give plasmids pTAFH.85, pT76H1 and pT76H2. Thus, the following vectors were cleaved and ligated:

pTAF.85 plus	Resulting Plasmid
pTAFH1 pYJ30 pYA2	pTAFH.85 pT76H1 pT76H2

#### EXAMPLE XV

##### Regulation Of $\beta$ -Galactosidase Production In *Pichia pastoris*

The production of  $\beta$ -galactosidase by several *Pichia pastoris* GS115 (NRRL Y-15851) transformants grown on different carbon sources and under different conditions was investigated. The transformed strains were grown in minimal medium containing 0.5  $\mu$ g/mL of biotin and 0.1% glucose at 30 °C until they reached stationary phase. The cells were then collected by centrifugation and transferred to minimal medium containing 0.5  $\mu$ g/mL of biotin and 0.5% methanol and grown for about 3-5 generations at 30 °C. After this initial growth on methanol, cells were collected by centrifugation and transferred to fresh minimal medium containing 0.5  $\mu$ g/mL of biotin and either 0.1% glucose or 0.3% methanol as carbon source. The cells were then incubated at 30 °C for about 80 hours, with samples being periodically withdrawn to determine the alcohol oxidase and  $\beta$ -galactosidase levels. After about 20-50 hours, the carbon source was depleted and thereafter the cells were maintained under the same carbon source starvation conditions. The results are summarized in Table I.

TABLE I

Maximal levels (incubation time, hrs) of  $\beta$ -galactosidase and alcohol oxidase (Units/OD<sub>500</sub>) in transformants of *Pichia pastoris* NRRL Y-15851

plasmid	$\beta$ -galactosidase <sup>a</sup>			Alcohol Oxidase <sup>a</sup>		
	1% glucose	glucose starvation	0.3% methanol	1% glucose	glucose starvation	0.3% methanol
PSAOH1	0	660 (20)	1361 (0)	0	35	530
PSAOH5	0.1-0.2	567 (20)	1168 (0)	0	60	550
PSAOH10	0	886 (20)	1559 (0)	0	167	425
PTAFH.85	0	0.17 (80)	0.5	0	nd	nd
PT76H1	0	3.20 (80)	0	0	nd	nd
PT76H2	0	nd	nd	0	nd	nd
PT76H3	0	20	781	0	nd	nd
PT76H4	0.3-0.6	40 (80)	3100	0	nd	nd

<sup>a</sup> Cells were withdrawn at different timepoints and  $\beta$ -galactosidase and alcohol oxidase activity assays were performed as described in the text.

nd = not determined

Alcohol oxidase was determined by the dye-peroxidase method described above (See Example VII) and  $\beta$ -galactosidase was determined as follows:

#### $\beta$ -Galactosidase Assay

A. Solutions required:

Z-buffer:		Final concentration
Na <sub>2</sub> HPO <sub>4</sub> • 7H <sub>2</sub> O	16.1 g	0.06 M
NaH <sub>2</sub> PO <sub>4</sub>	5.5 g	0.04 M
KCl	0.75 g	0.01 M
MgSO <sub>4</sub> • 7H <sub>2</sub> O	0.246 g	0.001 M
2-mercaptoethanol	2.7 mL	0.05 M
fill up to 1L; pH should be 7		

15 O-Nitrophenyl-β-D-galactoside (ONPG):

Dissolve 400 mg ONPG (Sigma N-1127) in 100 mL of distilled water to make a 4 mg/mL ONPG solution.

20 B. Assay Procedure:

1. Withdraw an aliquot from the culture medium (0.1-0.5 OD<sub>600</sub> of yeast cells), centrifuge and wash cell pellet with water.
2. Add 1 mL of Z buffer to the cell pellet, 30 μL of CHCl<sub>3</sub> and 30 μL of 0.1% SDS, vortex, incubate 5 minutes at 30 °C.
3. Start reaction by adding 0.2 mL of ONPG (4 mg/mL), vortex.
4. Stop reaction by adding 0.5 mL of a 1 M Na<sub>2</sub>CO<sub>3</sub> solution at appropriate time points (A<sub>420</sub> < 1).
5. Read absorbance of supernatant at 420 nm.

30 C. Calculation of β-galactosidase Activity Units:

1 U = 1 nmole of orthonitrophenol (ONP) formed per minute at 30 °C and a pH 7.  
 1 nmole of ONP has an absorbance at 420 nm (A<sub>420</sub>) of 0.0045 with a 1 cm pathlength; thus, an absorbance of 1 at 420 nm represents 222 nmole ONP/mL, or 378 nmole/1.7 mL since the total volume of supernatant being analyzed is 1.7 mL. Hence, Units expressed in the Tables are calculated:

$$U = \frac{A_{420}}{t(\text{min})} \times 378$$

The results presented in Table I indicate that a protein foreign to yeast, i.e., β-galactosidase, can be produced in *Pichia pastoris* regulated either by the presence of methanol in the nutrient medium or by carbon source starvation after growth on a catabolite repressing carbon source.

45 EXAMPLE XVIRegulation Of β-Galactosidase Production In *S. cerevisiae*

*Saccharomyces cerevisiae* SEY2102, a strain requiring uracil, leucine and histidine supplementation for survival, was transformed with plasmids pTAO13 and pT76U1. Transformed organisms were readily isolated by selecting for colonies which did not require uracil supplementation for growth. The isolated transformants, have been given the laboratory designation SEY2102-pTAO13, and SEY2102-pT76U1, respectively. SEY2102-pTAO13 has been deposited with the Northern Regional Research Center in Peoria, Illinois to insure access to the public as of the deposit date of August 31, 1984. This strain has been assigned accession number NRRL Y-15858.

Cells of NRRL Y-15858 and SEY2102-pT76U1 were incubated at 30 °C for about 3-4 generations in minimal medium containing 20 μg/mL of histidine and leucine and 5% glucose. Cells were then shifted, i.e.,

collected by centrifugation and transferred into YP medium with 3% of the carbon source indicated in Table II and grown for about 5 generations at 30°C. Cells were then incubated for an additional 50 hours under carbon source starvation conditions, and periodically sampled for  $\beta$ -galactosidase. The results are summarized in Table II.

TABLE II

Production of  $\beta$ -Galactosidase by *S. cerevisiae*

$\beta$ -galactosidase, Units/OD<sub>600</sub>

A. Alcohol oxidase regulatory region (pTA013)

Carbon Source (3%)	After 5 Generations	Starvation Conditions		
		6 hrs.	20 hrs.	50 hrs.

glucose	0.2	105	66	nd
fructose	0.3	30	31	28
ethanol	23	137	115	77
glycerol	640	806	656	788
galactose	982	960	651	766

B. p76 regulatory region (pT76U1)

Carbon Source (5%)	After 5 Generations	Starvation Conditions		
		12 hrs.	25 hrs.	30 hrs.

glucose	2.3	254	815	803
glycerol	470	nd	nd	nd

nd = not determined

These results indicate that a protein foreign to yeast, i.e.,  $\beta$ -galactosidase, can be produced by *Saccharomyces cerevisiae* regulated by the p72 (alcohol oxidase) and p76 regulatory regions under conditions of carbon source starvation when a catabolite repressing carbon source is employed for growth, or by growth of transformed *S. cerevisiae* cells on a relatively non-catabolite repressing carbon source such as glycerol or galactose.

The expression levels for  $\beta$ -galactosidase in *S. cerevisiae* under the control of the regulatory regions of this invention can be compared to the expression levels possible with other *S. cerevisiae* regulated promoters.

Promoter	Carbon Source	$\beta$ -galactosidase, Units/OD <sub>600</sub>
cytochrome C-lacZ fusion (CYC1)	Raffinose (3%)	460
galactose permease-lac-Z fusion (GAL2)	Galactose (2%)	450
Invertase-lacZ fusion (SUC2)	Glucose (0.1%)	160

It is seen that the regulatory regions of the invention surprisingly are at least as effective as, or more effective as *S. cerevisiae* promoters than promoters native to *S. cerevisiae*.

EXAMPLE XVII

Southern Hybridizations With Yeast Genomic DNA

Nine different methanol assimilating yeasts and one methanol non-assimilating yeast were grown on minimal media (IM1, See Example 1) plus 0.75% methanol or 1.0% glucose, respectively. Total chromosomal DNA was isolated as described in Example VI, i.e., total nucleic acids were isolated, treated with RNase A, extracted first with phenol/chloroform/isoamyl alcohol, then with chloroform/isoamyl alcohol and finally ethanol precipitated. The precipitated DNA was resuspended in a minimum volume of TE buffer and centrifuged to clean the DNA solution.

Southern hybridization filters were prepared as described in Example VI, i.e., 10 µg of total DNA from various yeast species was digested with excess *Hind*III, electrophoresed, DNA denatured, the gel neutralized and DNA transferred to nitrocellulose filters. Prehybridization conditions for these filters included treatment with 50% deionized formamide, 6x SSC, 5x Denhardt's, 1 mM EDTA, 0.1% SDS and 100 µg/mL denatured salmon sperm DNA, at 42°C overnight. The same conditions were used as a hybridization medium using <sup>32</sup>P-nick-translated probes at a final concentration of 10<sup>6</sup> cpm/mL. The probes included the cDNA inserts (*Pst*I fragments) from clones pPC 8.3, pPC 15.0 and pPC 6.7, as well as a 2.7 kbp *Bgl*II DNA fragment of the *P. pastoris* HIS4 gene. Each of these probes were separately used on identical filters for hybridization lasting 24 hours at 42°C. After hybridization the filters were washed twice for 15 minutes at room temperature, and three times at 65°C for 15 minutes in a solution containing 2x SSC, 1 mM EDTA, 0.1% SDS and 0.1% sodium pyrophosphate. Other washes were tried at lower stringency, i.e., at 55°C and 42°C, to confirm the hybridization results. The filters were then autoradiographed for 72 hours. The results of these hybridizations are summarized in Table III.

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TABLE III

Hybridization of *P. pastoris* Genes to Various Yeast

## Chromosomal DNA \*

		<i>P. pastoris</i>			
		<u>HIS4</u>	<u>pPC 8.3</u>	<u>pPC 15.0</u>	<u>pPC 6.7</u>
1)	<i>P. pastoris</i> NRRL Y-11430	+	+	+	+
2)	<i>P. pastoris</i> NRRL Y-1603	+	+	+	+
3)	<i>Hansenula</i> <i>capsulatum</i>	+	+	+	+
4)	<i>H. henricii</i>	+	+	(+)	+
5)	<i>H. nonfermentans</i>	+	+	+	+
6)	<i>H. polymorpha</i>	(+)	+	(+)	+
7)	<i>H. wickerhamii</i>	+	+	+	+
8)	<i>Torulopsis</i> <i>molischiana</i>	+	+	+	+
9)	<i>Saccharomyces</i> <i>cerevisiae</i>	(+)	-	-	-
10)	<i>P. pastoris</i> NRRL Y-15851	+	+	+	+

\*Legend: + hybridization

(+) weak hybridization

- no hybridization observed under the  
conditions employed

The results presented in Table III indicate that genes for polypeptides analogous to p76, p72 and p40 are present in virtually all methanol-assimilating yeasts. It is notable that none of these genes were observed by hybridization of DNA from a methanol non-assimilating yeast, *S. cerevisiae*, while homology



between the *P. pastoris* HIS4 gene and the HIS4 gene from *S. cerevisiae* was readily observed.

The examples have been provided merely to illustrate the practice of the invention and should not be read so as to limit the scope of the invention or the appended claims in any way. Reasonable variations and modifications, not departing from the essence and spirit of the invention, are contemplated to be within the scope of patent protection desired and sought.

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The following part of the description are preferred embodiments 1 to 34 presented in the format of claims.

1. A DNA fragment comprising a regulatory region derived from *Pichia pastoris* wherein said regulatory region is responsive to the presence of methanol in the culture medium with which a host organism for said DNA fragment is in contact, wherein said regulatory region is capable of controlling the transcription of messenger RNA when positioned at the 5' end of a DNA which codes for said messenger RNA, said regulatory region being selected from:
  - 20 (a) the regulatory region which controls the transcription of messenger RNA which codes for dihydroxyacetone synthetase obtainable from clone pPG6.0 (NRRL B-15867) from the 5'-HindIII-restriction site to the 3'-XhoI-restriction site;
  - 25 (b) the regulatory region which controls the transcription of messenger RNA which codes for alcohol oxidase obtainable from clone pPG4.0 (NRRL B-15868) from the 5'-EcoRI-restriction site to the 3'-EcoRV-restriction site;
  - 30 (c) the regulatory region which controls the transcription of messenger RNA which codes for p40 obtainable from clone pPG4.8 (NRRL B-15869) from the 5'-BamHI-restriction site to the 3'-SalI-restriction site.
2. A DNA fragment in accordance with embodiment 1 wherein said regulatory region is derived from the yeast species *Pichia pastoris*.
- 35 3. A DNA fragment in accordance with embodiment 2 wherein said yeast is *Pichia pastoris* NRRL Y-11430.
4. A DNA fragment in accordance with embodiment 3 wherein said regulatory region controls the transcription of messenger RNA which codes for the production of alcohol oxidase.
5. A DNA fragment in accordance with embodiment 3 wherein said regulatory region controls the transcription of messenger RNA which codes for the production of the polypeptide p76.
- 40 6. A DNA fragment in accordance with embodiment 3 wherein said regulatory region controls the transcription of messenger RNA which codes for the production of the polypeptide p40.
7. A DNA fragment in accordance with embodiment 4 further comprising the 3' sequence of DNA downstream of the DNA which codes for the production of alcohol oxidase.
8. A DNA fragment in accordance with embodiment 5 further comprising the 3' sequence of DNA downstream of the DNA which codes for the production of polypeptide P76.
9. A DNA fragment in accordance with embodiment 6 further comprising the 3' sequence of DNA downstream of the DNA which codes for the production of polypeptide p40.
10. A DNA fragment in accordance with embodiment 1 wherein said messenger RNA codes for the production of a heterologous polypeptide.
- 50 11. A DNA fragment in accordance with embodiment 4 wherein said fragment has the nucleotide sequence:

5' - ATGCTTCCAA      GATTCTGGTG      GGAATACTGC      TGATAGCCTA  
 ACGTTCATGA      TCAAAATTTA      ACTGTTCTAA      CCCCTACTTG  
 5      GACAGGCAAT      ATATAAACAG      AAGGAAGCTG      CCCTGTCTTA  
 AACCTTTTTT      TTTATCATCA      TTATTAGCTT      ACTTTCATAA  
 TTGCGACTGG      TTCCAATTGA      CAAGCTTTTG      ATTTTAACGA  
 10      CTTTAAACGA      CAACTTGAGA      AGATCAAAAA      ACAACTAATT  
 ATTCGAAACG-3'.

12. A DNA fragment in accordance with embodiment 4 wherein said fragment has the nucleotide sequence:

15      5' - AATGGCCCAA      CTGACAGTTT      AAACGCTGTC      TTGGAACCTA  
 .      ATATGACAAA      AGCGTGATCT      CATCCAAGAT      GAACTAAGTT  
 20      TGGTTCGTTG      AAATCCTAAC      GGCCAGTTGG      TCAAAAAGAA  
 .      ACTTCCAAAA      GTCGGCATAAC      CGTTTGTCCTT      GTTTGGTATT  
 GATTGACGAA      TGCTCAAAAA      TAATCTCATT      AATGCTTAGC  
 25      GCAGTCTCTC      TATCGCTTCT      GAACCCGGTG      GCACCTGTGC  
 CGAAACGCAA      ATGGGGAAAC      AACCCGCTTT      TTGGATGATT  
 ATGCATTGTC      TCCACATTGT      ATGCTTCCAA      GATTCTGGTG  
 GGAATACTGC      TGATAGCCTA      ACGTTCATGA      TCAAAATTTA  
 30      ACTGTTCTAA      CCCCTACTTG      GACAGGCAAT      ATATAAACAG  
 AAGGAAGCTG      CCCTGTCTTA      AACCTTTTTT      TTTATCATCA  
 TTATTAGCTT      ACTTTCATAA      TTGCGACTGG      TTCCAATTGA  
 35      CAAGCTTTTG      ATTTTAACGA      CTTTAAACGA      CAACTTGAGA  
 AGATCAAAAA      ACAACTAATT      ATTCGAAACG-3'.

40      13. A DNA fragment in accordance with embodiment 4 wherein said fragment has the nucleotide sequence:

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			5'-AGATCTAA	CATCCAAAGA
	CGAAAGGTTG	AATGAAACCT	TTTTGCCATC	CGACATCCAC
	AGGTCCATTG	TCACACATAA	GTGCCAAACG	CAACAGGAGG
5	GGATACACTA	GCAGCAGACG	TTGCAAACGC	AGGACTCATC
	CTCTTCTCTA	ACACCATTTT	GCATGAAAAC	AGCCAGTTAT
	GGGCTTGATG	GAGCTCGCTC	ATTCCAATTC	CTTCTATTAG
10	GCTACTAACA	CCATGACTTT	ATTAGCCTGT	CTATCCTGGC
	CCCCCTGGCG	AGGTCATGTT	TGTTTATTTT	CGAATGCAAC
	AAGCTCCGCA	TTACACCCGA	ACATCACTCC	AGATGAGGGC
	TTTCTGAGTG	TGGGGTCAAA	TAGTTTCATG	TTCCCAAATG
15	GCCCCAAAAT	GACAGTTTAA	ACGCTGTCTT	GGAACCTAAT
	ATGACAAAAG	CGTGATCTCA	TCCAAGATGA	ACTAAGTTTG
	GTTTCGTTGAA	ATCCTAACGG	CCAGTTGGTC	AAAAAGAAAC
20	TTCCAAAAGT	CGGCATACCG	TTTGTCTTGT	TTGGTATTGA
	TTGACGAATG	CTCAAAAATA	ATCTCATTA	TGCTTAGCGC
	AGTCTCTCTA	TCGCTTCTGA	ACCCGGTGCG	ACCTGTGCCG
	AAACGCAAAT	GGGGAAACAA	CCCGCTTTTT	GGATGATTAT
25	GCATTGTCCT	CCACATTGTA	TGCTTCCAAG	ATTCTGGTGG
	GAATACTGCT	GATAGCCTAA	CGTTCATGAT	CAAAATTTAA
	CTGTTCTAAC	CCCTACTTGG	ACAGGCAATA	TATAAACAGA
30	AGGAAGCTGC	CCTGTCTTAA	ACCTTTTTTT	TTATCATCAT
	TATTAGCTTA	CTTTCATAAT	TGCGACTGGT	TCCAATTGAC
	AAGCTTTTGA	TTTTAACGAC	TTTTAACGAC	AACCTGAGAA
	GATCAAAAAA	CAACTAATTA	TTCGAAACG-3'.	

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14. A DNA fragment in accordance with embodiment 5 wherein said fragment has the nucleotide sequence:

			5'-TT
40	CACCCATACA	ACTATAAACC	TTAGCAATTG
	AATTCATTGT	TCCGAGTTTA	ATATACTTGC
	AACCAAGGGA	TTTCAGCTTC	CTTACCCCAT
45	TTCCATTTAC	CCCCCACTGG	AGAGATCCGC
	AGATAATAGA	AAAAACAAT	TCGGACAAAT
	CTCAGCCAAT	TAAAGTCATT	CCATGCACTC
	CCGTTCCATC	CCTTTGTTGA	GCAACACCAT
50	TACGAAAGAG	GAACTTAAC	CGATACCTTG
	AGGCGCGAAT	GAGTTTAGCC	TAGATATCCT
	TGTTCGATAC	TTCTCCACAT	TCAGTCATAG
55	TGTATCATGA	AGAGACGGAA	ACGGGCATAA
			GGGTAACCGC

CAAATTATAT      AAAGACAACA      T'GCCCCAGTJ'      TAAAGTTT'IT  
 CTTTCCTATT      CTTGTATCCT      GAGTGACCGT      TGTGTTTAAT  
 ATAAAAAGTT      CGTTTTAACT      TAAGACCAAA      ACCAGTTACA  
 ACAAATTATA      ACCCCTCTAA      ACACTAAAGT      TCACTCTTAT  
 CAAACTATCA      AACATCAAAA-3'

15. A DNA fragment in accordance with embodiment 1 further comprising:  
 a polypeptide coding region; wherein said regulatory region is positioned at the 5' end of said polypeptide coding region.  
 16. A DNA fragment in accordance with embodiment 15 wherein said polypeptide coding region codes for the production of alcohol oxidase.  
 17. A DNA fragment in accordance with embodiment 16 wherein said fragment has the nucleotide sequence:

5'-ATG    GCT    ATC    CCC    GAA    GAG    TTT  
 3'-TAC    CGA    TAG    GGG    CTT    CTC    AAA  
 GAT    ATC    CTA    GTT    CTA    GGT    GGT    GGA    TTC    AGT    GGA    TCC  
 CTA    TAG    GAT    CAA    GAT    CCA    CCA    CCT    AGG    TCA    CCT    AGG  
 TGT    ATT    TCC    GGA    AGA    TTG    GCA    AAC    TTG    GAC    CAC    TCC  
 ACA    TAA    AGG    CCT    TCT    AAC    CGT    TTG    AAC    CTG    GTG    AGG  
 TTG    AAA    GTT    GGT    CTT    ATC    GAA    GCA    GGT    GAG    AAC    CAA  
 AAC    TTT    CAA    CCA    GAA    TAG    CTT    CGT    CCA    CTC    TTG    GTT  
 CCT    CAA    CAA    CCC    ATG    GGT    CTA    CCT    TCC    AGG    TAT    TTA  
 GGA    GTT    GTT    GGG    TAC    CCA    GAT    GGA    AGG    TCC    ATA    AAT  
 CCC    AAG    AAA    CAG    AAG    TTG    GAC    TCC    AAG    ACT    GCT    TCC  
 GGG    TTC    TTT    GTC    TTC    AAC    CTG    AGG    TTC    TGA    CGA    AGG  
 TTC    TAC    ACT    TCT    AAC    CCA    TCT    CCT    CAC    TTG    AAT    GGT  
 AAG    ATG    TGA    AGA    TTG    GGT    AGA    GGA    GTG    AAC    TTA    CCA  
 AGA    AGA    GCC    ATC    GTT    CCA    TGT    GCT    AAC    GTC    TTG    GGT  
 TCT    TCT    CGG    TAG    CAA    GGT    ACA    CGA    TTG    CAG    AAC    CCA  
 GGT    GGT    TCT    TCT    ATC    AAC    TTC    ATG    ATG    TAC    ACC    AGA  
 CCA    CCA    AGA    AGA    TAG    TTG    AAG    TAC    TAC    ATG    TGG    TCT  
 GGT    TCT    GCT    TCT    GAT    TCT    GAT    GAC    TTN    CAA    GCC    GAG  
 CCA    AGA    CGA    AGA    CTA    AGA    CTA    CTG    AAN    GTT    CGG    CTC  
 GGC    TCG    AAA    ACA    GAG    GAC    TTG    CTT    CCA    TTG    ATG    AAA  
 CCG    AGC    TTT    TGT    CTC    CTG    AAC    GAA    GGT    AAC    TAC    TTT  
 AAG    ACT    GAG    ACC    TAC    CAA    AGA    GCT    TGN    CAA    CNA    TAC  
 TTC    TGA    CTC    TGG    ATG    GTT    TCT    CGA    ACN    GTT    GNT    ATG  
 CCT    GAC    ATT    CAC    GGT    TTC    GAA    GGT    CCA    ATC    AAG    GTT  
 GGA    CTG    TAA    GTG    CCA    AAG    CTT    CCA    GGT    TAG    TTC    CAA  
 TCT    TTC    GGT    AAC    TAC    ACC    TAC    CCA    GTT    TGC    CAG    GAC  
 AGA    AAG    CCA    TTG    ATG    TGG    ATG    GGT    CAA    ACC    GTC    CTG

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	TTC	TTG	AGG	GCT	TCT	GAG	TCC	CAA	GGT	ATT	CCA	TAC
	AAG	AAC	TCC	CGA	AGA	CTC	AGG	GTT	CCA	TAA	CGT	ATG
5	GTT	GAC	GAT	CTG	GAA	GAC	TTG	GTA	CTG	ACT	CAC	GGT
	CAA	CTG	CTA	GAC	CTT	CTG	AAC	CAT	GAC	TGA	GTG	CCA
	GCT	GAA	CAC	TGG	TTG	AAG	TGG	ATC	AAC	AGA	GAC	ACT
	CGA	CTT	GTG	ACC	AAC	TTC	ACC	TAG	TTG	TCT	CTG	TGA
10	CGT	CGT	TCC	GAC	TCT	GCT	CAT	GCA	TTT	GTC	CAC	TCT
	GCA	GCA	AGG	CTG	AGA	CGA	GTA	CGT	AAA	CAG	GTG	AGA
	TCT	ACT	ATG	AGA	AAC	CAC	GAC	AAC	TTG	TAC	TTG	ATC
	AGA	TGA	TAC	TCT	TTG	GTG	CTG	TTG	AAC	ATG	AAC	TAG
15	TGT	AAC	ACG	AAG	GTC	GAC	AAA	ATT	ATT	GTC	GAA	GAC
	ACA	TTG	TGC	TTC	CAG	CTG	TTT	TAA	TAA	CAG	CTT	CTG
	GGA	AGA	GCT	GCT	GCT	GTT	AGA	ACC	GTT	CCA	AGC	AAG
	CCT	TCT	CGA	CGA	CGA	CAA	TCT	TGG	CAA	GGT	TCG	TTC
20	CCT	TTG	AAC	CCA	AAG	AAG	CCA	AGT	CAC	AAG	ATC	TAC
	GCA	AAC	TTG	GGT	TTC	TTC	GGT	TCA	GTG	TTC	TAG	ATG
	CGT	GCT	AGA	AAG	CAA	ATC	TTT	TTG	TCT	TGT	GGT	ACC
	GCA	CGA	TCT	TTC	GTT	TAG	AAA	AAC	AGA	ACA	CCA	TGG
25	ATC	TCC	TCT	CCA	TTG	GTT	TTG	CAA	AGA	TCC	GGT	TTT
	TAG	AGG	AGA	GGT	AAC	CAA	AAC	GTT	TCT	AGG	CCA	AAA
	GGT	GAC	CCA	ATC	AAG	TTG	AGA	GCC	GCT	GGT	GTT	AAG
	CCA	CTG	GGT	TAG	TTC	AAC	TCT	CGG	CGA	CCA	CAA	TTC
30	CCT	TTG	GTC	AAC	TTG	CCA	GGT	GTC	GGA	AGA	AAC	TTC
	GGA	AAC	CAG	TTG	AAC	GGT	CCA	CAG	CCT	TCT	TTG	AAG
	CAA	GAC	CAT	TAT	TGT	TTC	TTC	AGT	CCT	TAC	AGA	ATC
	GTT	CTG	GTA	ATA	ACA	AAG	AAG	TCA	GGA	ATG	TCT	TAG
35	AAG	CCT	CAG	TAC	GAG	TCT	TTC	GAT	GAC	TTC	GTC	CGT
	TTC	GCA	GTC	ATG	CTC	AGA	AAG	CTA	CTG	AAG	CAG	GCA
	GGT	GAT	GCT	GAG	ATT	CAA	AAG	AGA	GTC	GTT	GAC	CAA
	CCA	CTA	CGA	CTC	TAA	GTT	TTC	TCT	CAG	CAA	CTG	GTT
40	TGG	TAC	GCC	AAT	GGT	ACT	GGT	CCT	CTT	GCC	ACT	AAC
	ACC	ATG	CGG	TTA	CCA	TGA	CCA	GGA	GAA	CGG	TGA	TTG
	GGT	ATC	GAA	GCT	GGT	GTC	AAG	ATC	AGA	CCA	ACA	CCA
	CCA	TAG	CTT	CGA	CCA	CAG	TTC	TAG	TCT	GGT	TGT	GGT
45	GAA	GAA	CTC	TCT	CAA	ATG	GAC	GAA	TCC	TTC	CAG	GAG
	CTT	CTT	GAG	AGA	GTT	TAC	CTG	CTT	AGG	AAG	GTC	CTC
	GGT	TAC	AGA	GAA	TAC	TTC	GAA	GAC	AAG	CCA	GAC	AAG
	CCA	ATG	TCT	CTT	ATG	AAG	CTT	CTG	TTC	GGT	CTG	TTC
50	CCA	GTT	ATG	CAC	TAC	TCC	ATC	ATT	GCT	GGT	TTC	TTC
	GGT	CAA	TAC	GTG	ATG	AGG	TAG	TAA	CGA	CCA	AAG	AAG
	GGT	GAC	CAC	ACC	AAG	ATT	CCT	CCT	GGA	AAG	TAC	ATG
	CCA	CTG	GTG	TGG	TTC	TAA	GGA	GGA	CCT	TTC	ATG	TAC
55	ACT	ATG	TTC	CAC	TTC	TTG	GAA	TAC	CCA	TTC	TCC	AGA
	TGA	TAC	AAG	GTG	AAG	AAC	CTT	ATG	GGT	AAG	AGG	TCT
	GGT	TCC	ATT	CAC	ATT	ACC	TCC	CCA	GAC	CCA	TAC	GCA
	CCA	AGG	TAA	GTG	TAA	TGG	AGG	GGT	CTG	GGT	ATG	CGT

5	GCT	CCA	GAC	TTC	GAC	CGA	GGT	TTC	ATG	AAC	GAT	GAA
	CGA	GGT	CTG	AAG	CTG	GCT	CCA	AAG	TAC	TTG	CTA	CTT
	AGA	GAC	ATG	GCT	CCT	ATG	GTT	TGG	GCT	TAC	AAG	TCT
	TCT	CTG	TAC	CGA	GGA	TAC	CAA	ACC	CGA	ATG	TTC	TTC
10	TCT	AGA	GAA	ACC	GCT	AGA	AGA	AGT	GAC	CAC	TTT	GCC
	AGA	TCT	CTT	TGG	CGA	TCT	TCT	TCA	CTG	GTG	AAA	CGG
	GGT	GAG	GTC	ACT	TCT	CAC	CAC	CCT	CTG	TTC	CCA	TAC
	CCA	CTC	CAG	TGA	AGA	GTG	GTG	GGA	GAC	AAG	GGT	ATG
15	TCA	TCC	GAG	GCC	AGA	GCC	TTG	GAA	ATG	GAT	TTG	GAG
	AGT	AGG	CTC	CGG	TCT	CGG	AAC	CTT	TAC	CTA	AAC	CTC
	ACC	TCT	AAT	GCC	TAC	GGT	GGA	CCT	TTG	AAC	TTG	TCT
	TGG	AGA	TTA	CGG	ATG	CCA	CCT	GGA	AAC	TTG	AAC	AGA
20	GCT	GGT	CTT	GCT	CAC	GGT	TCT	TGG	ACT	CAA	CCT	TTG
	CGA	CCA	GAA	CGA	GTG	CCA	AGA	ACC	TGA	GTT	GGA	AAC
	AAG	AAG	CCA	ACT	GCA	AAG	AAC	GAA	GGC	CAC	GIT	ACT
	TTC	TTC	GGT	TGA	CGT	TTC	TTG	CTT	CCG	GTG	CAA	TGA
25	TCG	AAC	CAG	GTC	GAG	CTT	CAT	CCA	GAC	ATC	GAG	TAC
	AGC	TTG	GTC	CAG	CTC	GAA	GTA	GGT	CTG	TAG	CTC	ATG
	GAT	GAG	GAG	GAT	GAC	AAG	GCC	ATT	GAG	ACC	TAC	ATT
	CTA	CTC	CTC	CTA	CTG	TTC	CGG	TAA	CTC	TTG	ATG	TAA
30	CGT	GAG	CAC	ACT	GAG	ACC	ACA	TGG	CAC	TGT	CTG	GGA
	GCA	CTC	GTG	TGA	CTC	TGG	TGT	ACC	GTG	ACA	CCA	GGT
	ACC	TGT	TCC	ATC	GGT	CCA	AGA	GAA	GGT	TCC	AAG	ATC
	TGG	ACA	AGG	TAG	CCA	GGT	TCT	CTT	CCA	AGG	TTC	TAG
35	GTC	AAA	TGG	GGT	GGT	GTT	TIG	GAC	CAC	AGA	TCC	AAC
	CAG	TTT	ACC	CCA	CCA	CAA	AAC	CTG	GTG	TCT	AGG	TTG
	GTT	TAC	GGA	GTC	AAG	GGC	TIG	AAG	GTT	GGT	GAC	TTG
	CAA	ATG	CCT	CAG	TTC	CCG	AAC	TTC	CAA	CCA	CTG	AAC
40	TCC	GTG	TGC	CCA	GAC	AAT	GTT	GGT	TGT	AAC	ACC	TAC
	AGG	CAC	ACG	GGT	CTG	TTA	CAA	CCA	ACA	TTG	TGG	ATG
	ACC	ACC	GCT	CTT	TTG	ATC	GGT	GAA	AAG	ACT	GCC	ACT
	TGG	TGG	CGA	GAA	AAC	TAG	CCA	CTT	TTC	TGA	CGG	TGA
45	TTG	GTT	GGA	GAA	CAT	TTA	GGA	TAC	TCT	GGT	GAG	GCC
	AAC	CAA	CCT	CTT	CTA	AAT	CCT	ATG	AGA	CCA	CTC	CGG
	TTA	GAC	ATG	ACT	GTT	CCT	CAG	TTC	AAG	TTG	GGC	ACT
	AAT	CTG	TAC	TGA	CAA	GGA	GTC	AAG	TTC	AAC	CCG	TGA
50	TAC	GAG	AAG	ACC	GGT	CTT	GCT	AGA	TTC	TAA-3'		
	ATG	CTC	TTC	TGG	CCA	GAA	CGA	TCT	AAG	ATT-5'		

18. A DNA fragment in accordance with embodiment 15 wherein said polypeptide coding region codes for the production of polypeptide p76.

55 19. A DNA fragment in accordance with embodiment 15 wherein said polypeptide coding region codes for the production of polypeptide p40.

20. A DNA fragment in accordance with embodiment 15 wherein said polypeptide coding region codes for the production of a heterologous polypeptide.

21. A DNA fragment in accordance with embodiment 20 wherein said heterologous polypeptide is  $\beta$ -galactosidase.

22. A DNA fragment in accordance with embodiment 15 further comprising a 3' sequence of DNA downstream of the polypeptide coding region; wherein said 3' sequence of DNA is capable of controlling the polyadenylation, termination of transcription and termination of translation of messenger RNA coded for by said polypeptide coding region.

23. A DNA fragment in accordance with embodiment 15 or 22 wherein said DNA fragment further comprises one or more additional DNA sequences derived from the group consisting of

bacterial plasmid DNA,  
bacteriophage DNA,  
yeast plasmid DNA, and  
yeast chromosomal DNA.

24. A DNA fragment in accordance with embodiment 23 wherein said yeast chromosomal DNA comprises an autonomously replicating DNA sequence and a marker gene.

25. A gene coding for the production of alcohol oxidase, or a sub-unit thereof or an equivalent of such a gene or sub-unit.

26. A gene in accordance with embodiment 25 wherein said gene has the nucleotide sequence:

						5' -ATG	GCT	ATC	CCC	GAA	GAG	TTT
						3' -TAC	CGA	TAG	GGG	CTT	CTC	AAA
	GAT	ATC	CTA	GTT	CTA	GGT	GGT	GGA	TTC	AGT	GGA	TCC
	CTA	TAG	GAT	CAA	GAT	CCA	CCA	CCT	AGG	TCA	CCT	AGG
	TGT	ATT	TCC	GGA	AGA	TTG	GCA	AAC	TTG	GAC	CAC	TCC
25	ACA	TAA	AGG	CCT	TCT	AAC	CGT	TTG	AAC	CTG	GTG	AGG
	TTG	AAA	GTT	GGT	CTT	ATC	GAA	GCA	GGT	GAG	AAC	CAA
	AAC	TTT	CAA	CCA	GAA	TAG	CTT	CGT	CCA	CTC	TTG	GTT
	CCT	CAA	CAA	CCC	ATG	GGT	CTA	CCT	TCC	AGG	TAT	TTA
30	GGA	GTT	GTT	GGG	TAC	CCA	GAT	GGA	AGG	TCC	ATA	AAT
	CCC	AAG	AAA	CAG	AAG	TTG	GAC	TCC	AAG	ACT	GCT	TCC
	GGG	TTC	TTT	GTC	TTC	AAC	CTG	AGG	TTC	TGA	CGA	AGG
	TTC	TAC	ACT	TCT	AAC	CCA	TCT	CCT	CAC	TTG	AAT	GGT
35	AAG	ATG	TGA	AGA	TTG	GGT	AGA	GGA	GTG	AAC	TTA	CCA
	AGA	AGA	GCC	ATC	GTT	CCA	TGT	GCT	AAC	GTC	TTG	GGT
	TCT	TCT	CGG	TAG	CAA	GGT	ACA	CGA	TTG	CAG	AAC	CCA
	GGT	GGT	TCT	TCT	ATC	AAC	TTC	ATG	ATG	TAC	ACC	AGA
40	CCA	CCA	AGA	AGA	TAG	TTG	AAG	TAC	TAC	ATG	TGG	TCT
	GGT	TCT	GCT	TCT	GAT	TCT	GAT	GAC	TTN	CAA	GCC	GAG
	CCA	AGA	CGA	AGA	CTA	AGA	CTA	CTG	AAN	GTT	CGG	CTC
	GGC	TCG	AAA	ACA	GAG	GAC	TTG	CTT	CCA	TTG	ATG	AAA
45	CCG	AGC	TTT	TGT	CTC	CTG	AAC	GAA	GGT	AAC	TAC	TTT
	AAG	ACT	GAG	ACC	TAC	CAA	AGA	GCT	TGN	CAA	CNA	TAC
	TTC	TGA	CTC	TGG	ATG	GTT	TCT	CGA	ACN	GTT	GNT	ATG
	CCT	GAC	ATT	CAC	GGT	TTC	GAA	GGT	CCA	ATC	AAG	GTT
50	GGA	CTG	TAA	GTG	CCA	AAG	CTT	CCA	GGT	TAG	TTC	CAA
	TCT	TTC	GGT	AAC	TAC	ACC	TAC	CCA	GTT	TGC	CAG	GAC
	AGA	AAG	CCA	TTG	ATG	TGG	ATG	GGT	CAA	ACG	GTC	CTG

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	TTC	TTG	AGG	GCT	TCT	GAG	TCC	CAA	GGT	ATT	CCA	TAC
	AAG	AAC	TCC	CGA	AGA	CTC	AGG	GTT	CCA	TAA	CGT	ATG
	GTT	GAC	GAT	CTG	GAA	GAC	TTG	GTA	CTG	ACT	CAC	GGT
5	CAA	CTG	CTA	GAC	CTT	CTG	AAC	CAT	GAC	TGA	GTG	CCA
	GCT	GAA	CAC	TGG	TTG	AAG	TGG	ATC	AAC	AGA	GAC	ACT
	CGA	CTT	GTG	ACC	AAC	TTC	ACC	TAG	TTG	TCT	CTG	TGA
	CGT	CGT	TCC	GAC	TCT	GCT	CAT	GCA	TTT	GTC	CAC	TCT
	GCA	GCA	AGG	CTG	AGA	CGA	GTA	CGT	AAA	CAG	GTG	AGA
10	TCT	ACT	ATG	AGA	AAC	CAC	GAC	AAC	TTG	TAC	TTG	ATC
	AGA	TGA	TAC	TCT	TTG	GTG	CTG	TTG	AAC	ATG	AAC	TAG
	TGT	AAC	ACG	AAG	GTC	GAC	AAA	ATT	ATT	GTC	GAA	GAC
	ACA	TTG	TGC	TTC	CAG	CTG	TTT	TAA	TAA	CAG	CTT	CTG
15	GGA	AGA	GCT	GCT	GCT	GTT	AGA	ACC	GTT	CCA	AGC	AAG
	CCT	TCT	CGA	CGA	CGA	CAA	TCT	TGG	CAA	GGT	TCG	TTC
	CCT	TTG	AAC	CCA	AAG	AAG	CCA	AGT	CAC	AAG	ATC	TAC
	GCA	AAC	TTG	GGT	TTC	TTC	GGT	TCA	GTG	TTC	TAG	ATG
20	CGT	GCT	AGA	AAG	CAA	ATC	TTT	TTG	TCT	TGT	GGT	ACC
	GCA	CGA	TCT	TTC	GTT	TAG	AAA	AAC	AGA	ACA	CCA	TGG
	ATC	TCC	TCT	CCA	TTG	GTT	TTG	CAA	AGA	TCC	GGT	TTT
	TAG	AGG	AGA	GGT	AAC	CAA	AAC	GTT	TCT	AGG	CCA	AAA
25	GGT	GAC	CCA	ATC	AAG	TTG	AGA	GCC	GCT	GGT	GTT	AAG
	CCA	CTG	GGT	TAG	TTC	AAC	TCT	CGG	CGA	CCA	CAA	TTC
	CCT	TTG	GTC	AAC	TTG	CCA	GGT	GTC	GGA	AGA	AAC	TTC
	GGA	AAC	CAG	TTG	AAC	GGT	CCA	CAG	CCT	TCT	TTG	AAG
30	CAA	GAC	CAT	TAT	TGT	TTC	AGT	AGT	CCT	TAC	AGA	ATC
	GTT	CTG	GTA	ATA	ACA	AAG	AAG	TCA	GGA	ATG	TCT	TAG
	AAG	CCT	CAG	TAC	GAG	TCT	TTC	GAT	GAC	TTC	GTC	CGT
	TTC	GCA	GTC	ATG	CTC	AGA	AAG	CTA	CTG	AAG	CAG	GCA
35	GGT	GAT	GCT	GAG	ATT	CAA	AAG	AGA	GTC	GTT	GAC	CAA
	CCA	CTA	CGA	CTC	TAA	GTT	TTC	TCT	CAG	CAA	CTG	GTT
	TGG	TAC	GCC	AAT	GGT	ACT	GGT	CCT	CTT	GCC	ACT	AAC
	ACC	ATG	CGG	TTA	CCA	TGA	CCA	GGA	GAA	CGG	TGA	TTG
40	GGT	ATC	GAA	GCT	GGT	GTC	AAG	ATC	AGA	CCA	ACA	CCA
	CCA	TAG	CTT	CGA	CCA	CAG	TTC	TAG	TCT	GGT	TGT	GGT
	GAA	GAA	CTC	TCT	CAA	ATG	GAC	GAA	TCC	TTC	CAG	GAG
	CTT	CTT	GAG	AGA	GTT	TAC	CTG	CTT	AGG	AAG	GTC	CTC
45	GGT	TAC	AGA	GAA	TAC	TTC	GAA	GAC	AAG	CCA	GAC	AAG
	CCA	ATG	TCT	CTT	ATG	AAG	CTT	CTG	TTC	GGT	CTG	TTC
	CCA	GTT	ATG	CAC	TAC	TCC	ATC	ATT	GCT	GGT	TTC	TTC
	GGT	CAA	TAC	GTG	ATG	AGG	TAG	TAA	CGA	CCA	AAG	AAG
50	GGT	GAC	CAC	ACC	AAG	ATT	CCT	CCT	GGA	AAG	TAC	ATG
	CCA	CTG	GTG	TGG	TTC	TAA	GGA	GGA	CCT	TTC	ATG	TAC
	ACT	ATG	TTC	CAC	TTC	TTG	GAA	TAC	CCA	TTC	TCC	AGA
	TGA	TAC	AAG	GTG	AAG	AAC	CTT	ATG	GGT	AAG	AGG	TCT
55	GGT	TCC	ATT	CAC	ATT	ACC	TCC	CCA	GAC	CCA	TAC	GCA
	CCA	AGG	TAA	GTG	TAA	TGG	AGG	GGT	CTG	GGT	ATG	CGT



	GCT	CCA	GAC	TTC	GAC	CGA	GGT	TTC	ATG	AAC	GAT	GAA
	CGA	GGT	CTG	AAG	CTG	GCT	CCA	AAG	TAC	TTG	CTA	CTT
5	AGA	GAC	ATG	GCT	CCT	ATG	GTT	TGG	GCT	TAC	AAG	TCT
	TCT	CTG	TAC	CGA	GGA	TAC	CAA	ACC	CGA	ATG	TTC	TTC
	TCT	AGA	GAA	ACC	GCT	AGA	AGA	AGT	GAC	CAC	TTT	GCC
	AGA	TCT	CTT	TGG	CGA	TCT	TCT	TCA	CTG	GTG	AAA	CGG
10	GGT	GAG	GTC	ACT	TCT	CAC	CAC	CCT	CTG	TTC	CCA	TAC
	CCA	CTC	CAG	TGA	AGA	GTG	GTG	GGA	GAC	AAG	GGT	ATG
	TCA	TCC	GAG	GCC	AGA	GCC	TTG	GAA	ATG	GAT	TTG	GAG
	AGT	AGG	CTC	CGG	TCT	CGG	AAC	CTT	TAC	CTA	AAC	CTC
15	ACC	TCT	AAT	GCC	TAC	GGT	GGA	CCT	TTG	AAC	TTG	TCT
	TGG	AGA	TTA	CGG	ATG	CCA	CCT	GGA	AAC	TTG	AAC	AGA
	GCT	GGT	CTT	GCT	CAC	GGT	TCT	TGG	ACT	CAA	CCT	TTG
	CGA	CCA	GAA	CGA	GTG	CCA	AGA	ACC	TGA	GTT	GGA	AAC
20	AAG	AAG	CCA	ACT	GCA	AAG	AAC	GAA	GGC	CAC	GIT	ACT
	TTC	TTC	GGT	TGA	CGT	TTC	TTG	CTT	CCG	GTG	CAA	TGA
	TCG	AAC	CAG	GTC	GAG	CTT	CAT	CCA	GAC	ATC	GAG	TAC
	AGC	TTG	GTC	CAG	CTC	GAA	GTA	GGT	CTG	TAG	CTC	ATG
25	GAT	GAG	GAG	GAT	GAC	AAG	GCC	ATT	GAG	ACC	TAC	ATT
	CTA	CTC	CTC	CTA	CTG	TTC	CGG	TAA	CTC	TTG	ATG	TAA
	CGT	GAG	CAC	ACT	GAG	ACC	ACA	TGG	CAC	TGT	CTG	GGA
	GCA	CTC	GTG	TGA	CTC	TGG	TGT	ACC	GTG	ACA	CCA	GGT
30	ACC	TGT	TCC	ATC	GGT	CCA	AGA	GAA	GGT	TCC	AAG	ATC
	TGG	ACA	AGG	TAG	CCA	GGT	TCT	CTT	CCA	AGG	TTC	TAG
	GTC	AAA	TGG	GGT	GGT	GTT	TIG	GAC	CAC	AGA	TCC	AAC
	CAG	TTT	ACC	CCA	CCA	CAA	AAC	CTG	GTG	TCT	AGG	TTG
35	GTT	TAC	GGA	GTC	AAG	GGC	TIG	AAG	GTT	GGT	GAC	TTG
	CAA	ATG	CCT	CAG	TTC	CCG	AAC	TTC	CAA	CCA	CTG	AAC
	TCC	GTG	TGC	CCA	GAC	AAT	GTT	GGT	TGT	AAC	ACC	TAC
	AGG	CAC	ACG	GGT	CTG	TTA	CAA	CCA	ACA	TTG	TGG	ATG
40	ACC	ACC	GCT	CTT	TTG	ATC	GGT	GAA	AAG	ACT	GCC	ACT
	TGG	TGG	CGA	GAA	AAC	TAG	CCA	CTT	TTC	TGA	CGG	TGA
	TTG	GTT	GGA	GAA	CAT	TTA	GGA	TAC	TCT	GGT	GAG	GCC
	AAC	CAA	CCT	CTT	CTA	AAT	CCT	ATG	AGA	CCA	CTC	CGG
45	TTA	GAC	ATG	ACT	GTT	CCT	CAG	TTC	AAG	TTG	GGC	ACT
	AAT	CTG	TAC	TGA	CAA	GGA	GTC	AAG	TTC	AAC	CCG	TGA
	TAC	GAG	AAG	ACC	GGT	CTT	GCT	AGA	TTC	TAA-3'		
	ATG	CTC	TTC	TGG	CCA	GAA	CGA	TCT	AAG	ATT-5'		

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27. A gene coding for the production of polypeptide p76, or a sub-unit thereof or an equivalent of such a gene or sub-unit.

28. A gene coding for the production of polypeptide p40, or a sub-unit thereof or an equivalent of such a gene or sub-unit.

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29. A DNA fragment in accordance with embodiment 23 wherein said fragment is in the form of a closed circular hybrid plasmid.

30. A transformed yeast strain; where in said transformed yeast strain is a host for recombinant DNA material;

wherein said recombinant DNA material comprises:

- (1) a DNA fragment, and
  - (2) a polypeptide coding region; wherein said DNA fragment is responsive to at least one of the conditions selected from the group consisting of:
    - (i) the presence of methanol in the culture medium with which a host organism for said DNA fragment is in contact, and
    - wherein said regulatory region is positioned at the 5' end of said polypeptide coding region; and,
    - wherein said transformed yeast strain is capable of expressing the polypeptide coded for by said polypeptide coding region.
31. A transformed yeast strain in accordance with embodiment 30 wherein said transformed yeast strain is capable of growth on methanol as carbon and energy source.
32. A transformed yeast strain in accordance with embodiment 30 wherein said recombinant DNA material further comprises a second DNA fragment; wherein said second DNA fragment is capable of controlling the polyadenylation, termination of transcription and termination of translation of messenger RNA when positioned at the 3' end of the polypeptide coding region which codes for the production of said messenger RNA.
33. A process for preparing polypeptides comprising cultivating a transformed yeast strain in a nutrient medium containing methanol wherein said transformed yeast strain is capable of expressing an inserted polypeptide coding sequence derived from recombinant DNA material; wherein said recombinant DNA material comprises
- (1) a methanol responsive DNA fragment, and
  - (2) a polypeptide coding region; wherein said methanol responsive DNA fragment is positioned at the 5' end of said polypeptide coding region.
34. A process in accordance with embodiment 33 further comprising;
- isolating and purifying said polypeptide.

#### Claims

Claims for the following Contracting States : BE, CH, DE, FR, GB, IT, LI, LU, NL, SE

1. A DNA fragment comprising a regulatory region derived from *Pichia pastoris*, wherein said regulatory region is responsive to the presence of methanol in the culture medium with which a host organism for said DNA fragment is in contact, wherein said regulatory region is capable of controlling the transcription of messenger RNA when positioned at the 5' end of a DNA which codes for said messenger RNA, said regulatory region being selected from:
  - (a) the regulatory region which controls the transcription of messenger RNA which codes for dihydroxyacetone synthetase obtainable from clone pPG6.0 (NRRL B-15867) from the 5'-HindIII-restriction site to the 3'-XhoI-restriction site;
  - (b) the regulatory region which controls the transcription of messenger RNA which codes for alcohol oxidase obtainable from clone pPG4.0 (NRRL B-15868) from the 5'-EcoRI-restriction site to the 3'-EcoRV-restriction site;
  - (c) the regulatory region which controls the transcription of messenger RNA which codes for p40 obtainable from clone pPG4.8 (NRRL B-15869) from the 5'-BamHI-restriction site to the 3'-SalI-restriction site.
2. The DNA fragment of claim 1 further comprising a polypeptide coding region, wherein said regulatory region is positioned at the 5' end of said polypeptide coding region.
3. The DNA fragment of claim 2 further comprising a 3' sequence of DNA downstream of the polypeptide coding region, wherein said 3' sequence of DNA is capable of controlling the polyadenylation, termination of transcription and termination of translation of messenger RNA coded for by said polypeptide coding region.
4. The DNA fragment of claim 1 characterized in that said regulatory region is derived from *Pichia pastoris* NRRL Y-11430.
5. The DNA fragment of claim 3 further comprising one or more additional DNA sequences derived from the group of bacterial plasmid DNA, bacteriophage DNA, yeast plasmid DNA, and yeast chromosomal DNA.

6. The DNA fragment of claim 5 wherein said yeast chromosomal DNA comprises an autonomously replicating DNA sequence and a marker gene.
7. The DNA fragment of any of claims 2 - 6 characterized in that said polypeptide coding region codes for a heterologous polypeptide.
8. The DNA fragment of any of claims 2 - 6 characterized in that said polypeptide coding region codes for alcohol oxidase.
9. The DNA fragment of any of claims 2 - 6 characterized in that said polypeptide coding region codes for dihydroxyacetone synthase.
10. The DNA fragment of any of claims 2 - 6 characterized in that said polypeptide coding region codes for polypeptide p40.
11. The DNA fragment of any of claims 2 - 6 characterized in that said fragment is in the form of a closed circular hybrid plasmid.
12. A gene, derived from *Pichia pastoris*, coding for alcohol oxidase, said gene having as regulatory region a regulatory region comprised in the DNA fragment of claim 1.
13. A gene, derived from *Pichia pastoris*, coding for dihydroxyacetone synthase, said gene having as regulatory region a regulatory region comprised in the DNA fragment of claim 1.
14. A gene, derived from *Pichia pastoris*, coding for polypeptide p40, said gene having as regulatory region a regulatory region comprised in the DNA fragment of claim 1.
15. A transformed yeast strain obtained by transforming a *Pichia pastoris* host with an expression vector carrying recombinant DNA material, wherein said recombinant DNA material comprises the DNA fragment of claim 3.
16. The transformed yeast strain of claim 15, wherein said *Pichia pastoris* host is GS 115 (NRRL Y-15851).
17. A process for preparing polypeptides comprising cultivating the transformed yeast strain of claim 15 or 16 in a nutrient medium and inducing the expression in the presence of methanol and recovering the polypeptides.
18. The process of claim 17 wherein the nutrient medium for culturing the transformed yeast strain of claim 15 or 16 contains methanol.

**Claims for the following Contracting State : AT**

1. A process for preparing polypeptides comprising cultivating a transformed yeast strain obtained by transforming a *Pichia pastoris* host with an expression vector carrying recombinant DNA material, wherein said recombinant DNA material comprises a DNA fragment comprising a regulatory region derived from *Pichia pastoris* wherein said regulatory region is responsive to the presence of methanol in the culture medium with which a host organism for said DNA fragment is in contact, wherein said regulatory region is capable of controlling the transcription of messenger RNA when positioned at the 5' end of a DNA which codes for said messenger RNA, said regulatory region being selected from:
  - (a) the regulatory region which controls the transcription of messenger RNA which codes for dihydroxyacetone synthase obtainable from clone pPG6.0 (NRRL B-15867) from the 5'-HindIII-restriction site to the 3'-XhoI-restriction site;
  - (b) the regulatory region which controls the transcription of messenger RNA which codes for alcohol oxidase obtainable from clone pPG4.0 (NRRL B-15868) from the 5'-EcoRI-restriction site to the 3'-EcoRV-restriction site;
  - (c) the regulatory region which controls the transcription of messenger RNA which codes for p40 obtainable from clone pPG4.8 (NRRL B-15869) from the 5'-BamHI-restriction site to the 3'-SalI-restriction site;

wherein said cultivating takes place in a nutrient medium and inducing the expression in the presence of methanol and recovering the polypeptides.

2. The process of claim 1 wherein said DNA fragment further comprises a polypeptide coding region, wherein said regulatory region is positioned at the 5' end of said polypeptide coding region.
3. The process of claim 2 wherein said DNA fragment further comprises a 3' sequence of DNA downstream of the polypeptide coding region, wherein said 3' sequence of DNA is capable of controlling the polyadenylation, termination of transcription and termination of translation of messenger RNA coded for by said polypeptide coding region.
4. The process of claim 1 characterized in that said regulatory region is derived from *Pichia pastoris* NRRL Y-11430.
5. The process of claim 3 wherein said DNA fragment further comprises one or more additional DNA sequences derived from the group bacterial plasmid DNA, bacteriophage DNA, yeast plasmid DNA, and yeast chromosomal DNA.
6. The process of claim 5 wherein said yeast chromosomal DNA comprises an autonomously replicating DNA sequence and a marker gene.
7. The process of any of claims 2 - 6 characterized in that said polypeptide coding region codes for a heterologous polypeptide.
8. The process of any of claims 2 - 6 characterized in that said polypeptide coding region codes for alcohol oxidase.
9. The process of any of claims 2 - 6 characterized in that said polypeptide coding region codes for dihydroxyacetone synthase.
10. The process of any of claims 2 - 6 characterized in that said polypeptide coding region codes for polypeptide p40.
11. The process of any of claims 2-6 characterized in that said fragment is in the form of a closed circular hybrid plasmid.
12. A gene, derived from *Pichia pastoris*, coding for alcohol oxidase, said gene having as regulatory region a regulatory region comprised in the DNA fragment of claim 1.
13. A gene, derived from *Pichia pastoris*, coding for dihydroxyacetone synthase, said gene having as regulatory region a regulatory region comprised in the DNA fragment of claim 1.
14. A gene, derived from *Pichia pastoris*, coding for polypeptide p40, said gene having as regulatory region a regulatory region comprised in the DNA fragment of claim 1.
15. The process of claim 1, wherein said *Pichia pastoris* host is GS 115 (NRRL Y-15851).
16. The process of any of claims 1-15 wherein the nutrient medium for culturing the transformed yeast strain contains methanol.

#### Patentansprüche

Patentansprüche für folgende Vertragsstaaten : BE, CH, DE, FR, GB, IT, LI, LU, NL, SE

1. DNA-Fragment, das eine regulatorische Region, die aus *Pichia pastoris* stammt, umfaßt, wobei die regulatorische Region auf die Anwesenheit von Methanol im Kulturmedium anspricht, mit dem ein Wirtsorganismus für dieses DNA-Fragment in Kontakt ist, wobei die regulatorische Region fähig ist, die Transkription von Messenger RNA zu kontrollieren, wenn sie am 5' Ende einer DNA positioniert ist, die für diese Messenger RNA codiert, wobei die regulatorische Region ausgewählt ist aus:

- a) die regulatorische Region, die die Transkription von Messenger RNA kontrolliert, die für Dihydroxyacetonsynthase codiert, wobei die Region aus Klon pPG 6.0 (NRRL B-15867) von der 5'-HindIII-Schnittstelle bis zur 3'-XhoI-Schnittstelle erhältlich ist;
  - b) die regulatorische Region, die die Transkription von Messenger RNA kontrolliert, die für Alkoholoxidase codiert, wobei die regulatorische Region aus Klon pPG 4.0 (NRRL B-15868) von der 5' EcoRI-Schnittstelle bis zur 3' EcoRV-Schnittstelle erhältlich ist;
  - c) die regulatorische Region, die die Transkription von Messenger RNA kontrolliert, die für p40 codiert, wobei die regulatorische Region aus Klon pPG4.8 (NRRL B-15869) von der 5'-BamHI-Schnittstelle bis zu der 3'-SalI-Schnittstelle erhältlich ist.
2. DNA-Fragment nach Anspruch 1, wobei dieses weiter eine Polypeptid codierende Region umfaßt, wobei die regulatorische Region am 5' Ende der Polypeptid codierenden Region positioniert ist.
  3. DNA-Fragment nach Anspruch 2, wobei dieses weiter eine 3'-DNA-Sequenz stromabwärts der Polypeptid codierenden Region umfaßt, wobei die 3' DNA-Sequenz fähig ist, die Polyadenylierung, Termination der Transkription und Termination der Translation von Messenger RNA, für die die Polypeptid codierende Region codiert, zu kontrollieren.
  4. DNA-Fragment nach Anspruch 1, dadurch gekennzeichnet, daß die regulatorische Region aus *Pichia pastoris* NRRL Y-11430 stammt.
  5. DNA-Fragment nach Anspruch 3, wobei dieses weiter eine oder mehrere zusätzliche DNA-Sequenzen umfaßt, wobei diese aus der Gruppe Bakterienplasmid-DNA, Bakteriophagen-DNA, Hefepiasmid-DNA und Hefe-chromosomale DNA stammen.
  6. DNA-Fragment nach Anspruch 5, wobei die chromosomale Hefe-DNA eine autonom replizierende DNA-Sequenz und ein Marker-Gen umfaßt.
  7. DNA-Fragment nach einem der Ansprüche 2-6, dadurch gekennzeichnet, daß die Polypeptid codierende Region für ein heterologes Polypeptid codiert.
  8. DNA-Fragment nach einem der Ansprüche 2-6, dadurch gekennzeichnet, daß die Polypeptid codierende Region für Alkoholoxidase codiert.
  9. DNA-Fragment nach einem der Ansprüche 2-6, dadurch gekennzeichnet, daß die Polypeptid codierende Region für Dihydroxyacetonsynthase codiert.
  10. DNA-Fragment nach einem der Ansprüche 2-6, dadurch gekennzeichnet, daß die Polypeptid codierende Region für Polpeptid p40 codiert.
  11. DNA-Fragment nach einem der Ansprüche 2-6, dadurch gekennzeichnet, daß das Fragment in der Form eines geschlossenen zirkulären Hybridplasmids ist.
  12. Aus *Pichia pastoris* stammendes Gen, das für Alkoholoxidase codiert, wobei das Gen als regulatorische Region eine regulatorische Region hat, die in dem DNA-Fragment von Anspruch 1 enthalten ist.
  13. Aus *Pichia pastoris* stammendes Gen, das für Dihydroxyacetonsynthase codiert, wobei das Gen als regulatorische Region eine regulatorische Region hat, die in dem DNA-Fragment von Anspruch 1 enthalten ist.
  14. Aus *Pichia pastoris* stammendes Gen, das für Polypeptid p40 codiert, wobei das Gen als regulatorische Region eine regulatorische Region hat, die in dem DNA-Fragment von Anspruch 1 enthalten ist.
  15. Transformierter Hefestamm, der erhalten wird durch Transformieren eines *Pichia pastoris* Wirts mit einem Expressionsvektor, der rekombinantes DNA-Material enthält, wobei das rekombinante DNA-Material das DNA-Fragment von Anspruch 3 umfaßt.
  16. Transformierter Hefestamm nach Anspruch 15, wobei der *Pichia pastoris* Wirt GS 115 (NRRL Y-15851)

ist.

17. Verfahren zum Herstellen von Polypeptiden, wobei dieses das Kultivieren des transformierten Hefestamms von Anspruch 15 oder 16 in einem Wachstumsmedium und Induzieren der Expression in Anwesenheit von Methanol und Gewinnen der Polypeptide umfaßt.

18. Verfahren von Anspruch 17, wobei das Wachstumsmedium zum Kultivieren des transformierten Hefestamms von Anspruch 15 oder 16 Methanol enthält.

**Patentansprüche für folgenden Vertragsstaat : AT**

1. Verfahren zum Herstellen von Polypeptiden, das das Kultivieren eines transformierten Hefestamms umfaßt, der erhalten wird durch Transformieren eines *Pichia pastoris* Wirts mit einem Expressionsvektor, der rekombinantes DNA-Material enthält, wobei das rekombinante DNA-Material ein DNA-Fragment enthält, wobei die regulatorische Region auf die Anwesenheit von Methanol im Kulturmedium mit dem ein Wirtsorganismus für das DNA-Fragment in Kontakt ist, anspricht, wobei die regulatorische Region fähig ist, die Transkription von Messenger RNA zu kontrollieren, wenn sie am 5' Ende der DNA positioniert ist, die für die Messenger RNA codiert, wobei die regulatorische Region ausgewählt ist aus:
  - a) die regulatorische Region, die die Transkription von Messenger RNA kontrolliert, die für Dihydroxyacetonsynthase codiert, wobei die Region aus Klon pPG 6.0 (NRRL B-15867) von der 5' HindIII-Schnittstelle bis zur 3' XhoI-Schnittstelle erhältlich ist;
  - b) die regulatorische Region, die die Transkription von Messenger RNA kontrolliert, die für Alkoholoxidase codiert, wobei die regulatorische Region aus Klon pPG 4.0 (NRRL B-15868) von der 5' EcoRI-Schnittstelle bis zur 3' EcoRV-Schnittstelle erhältlich ist;
  - c) die regulatorische Region, die die Transkription von Messenger RNA kontrolliert, die für p40 codiert, wobei die regulatorische Region aus Klon pPG4.8 (NRRL B-15869) von der 5' BamHI-Schnittstelle bis zu der 3' SalI-Schnittstelle erhältlich ist,
 wobei das Kultivieren in einem Wachstums-Medium stattfindet, und Induzieren der Expression in Anwesenheit von Methanol und Gewinnen der Polypeptide.
2. Verfahren nach Anspruch 1, wobei das DNA-Fragment weiter eine Polypeptid codierende Region umfaßt, wobei die regulatorische Region am 5' Ende der Polypeptid codierenden Region positioniert ist.
3. Verfahren nach Anspruch 2, wobei das DNA-Fragment weiter die 3' DNA-Sequenz stromabwärts der Polypeptid codierenden Region umfaßt, wobei die 3' DNA-Sequenz fähig ist, die Polyadenylation, Termination der Transkription und Termination der Translation von Messenger RNA, für die die Polypeptid codierende Region codiert, zu kontrollieren.
4. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die regulatorische Region aus *Pichia pastoris* NRRL Y-11430 stammt.
5. Verfahren nach Anspruch 3, wobei das DNA-Fragment weiter eine oder mehrere zusätzliche DNA-Sequenzen umfaßt, die aus der Gruppe Bakterienplasmid-DNA, Bakteriophagen-DNA, Hefeplasmid-DNA und chromosomale Hefe-DNA stammen.
6. Verfahren nach Anspruch 5, wobei die chromosomale Hefe-DNA eine autonom replizierende DNA-Sequenz und ein Marker-Gen enthält.
7. Verfahren nach einem der Ansprüche 2-6, dadurch gekennzeichnet, daß die Polypeptid codierende Region für ein heterologes Polypeptid codiert.
8. Verfahren nach einem der Ansprüche 2-6, dadurch gekennzeichnet, daß die Polypeptid codierende Region für Alkoholoxidase codiert.
9. Verfahren nach einem der Ansprüche 2-6, dadurch gekennzeichnet, daß die Polypeptid codierende Region für Dihydroxyacetonsynthase codiert.

10. V r fahren nach einem der Ansprüch 2-6, dadurch gekennzeichnet, daß die Polypeptid codierende Region für Polypeptid p40 codiert.
11. Verfahren nach einem der Ansprüche 2-6, dadurch gekennzeichnet, daß das Fragment in Form eines geschlossenen zirkulären Hybridplasmids ist.
12. Aus *Pichia pastoris* stammendes Gen, das für Alkoholoxidase codiert, wobei das Gen als regulatorische Region eine regulatorische Region hat, die in dem DNA-Fragment von Anspruch 1 enthalten ist.
13. Aus *Pichia pastoris* stammendes Gen, das für Dihydroxyacetonsynthase codiert, wobei das Gen als regulatorische Region eine regulatorische Region hat, die in dem DNA-Fragment von Anspruch 1 enthalten ist.
14. Aus *Pichia pastoris* stammendes Gen, das für Polypeptid p40 codiert, wobei das Gen als regulatorische Region eine regulatorische Region hat, die in dem DNA-Fragment von Anspruch 1 enthalten ist.
15. Verfahren nach Anspruch 1, wobei der *Pichia pastoris* Wirt GS 115 (NRRL Y-15851) ist.
16. Verfahren nach einem der Ansprüche 1-15, wobei das Wachstums-Medium zum Kultivieren des transformierten Hefestammes Methanol enthält.

#### Revendications

Revendications pour les Etats contractants suivants : BE, CH, DE, FR, GB, IT, LI, LU, NL, SE

1. Fragment d'ADN comprenant une région régulatrice obtenu à partir de *Pichia pastoris*, dans lequel cette région régulatrice répond à la présence de méthanol dans le milieu de culture avec lequel un organisme hôte pour ce fragment d'ADN est en contact, dans lequel cette région régulatrice est capable de commander la transcription de l'ARN messenger lorsqu'il est disposé à l'extrémité 5' d'un ADN qui code pour cet ARN messenger, cette région régulatrice étant choisie parmi :
  - (a) la région régulatrice qui commande la transcription de l'ARN messenger qui code pour la dihydroxyacétone synthétase pouvant être obtenue à partir d'un clone pPG6.0 (NRRL B-15867) du site de restriction 5'-HindIII au site de restriction 3'-XhoI;
  - (b) la région régulatrice qui commande la transcription de l'ARN messenger qui code pour l'alcool oxydase pouvant être obtenu à partir du clone pPG4.0 (NRRL B-15868) du site de restriction 5'-EcoRI au site de restriction 3'-EcoRV;
  - (c) la région régulatrice qui commande la transcription de l'ARN messenger qui code pour le p40 pouvant être obtenu à partir du clone pPG4.8 (NRRL B-15869) du site de restriction 5'-BamHI au site de restriction 3'-SalI
2. Fragment d'ADN selon la revendication 1, comprenant en outre une région codant pour un polypeptide, dans lequel cette région régulatrice est placée à l'extrémité 5' de cette région codant pour un polypeptide.
3. Fragment d'ADN selon la revendication 2, comprenant en outre une séquence 3' d'ADN en aval de la région de codage du polypeptide, dans lequel cette séquence 3' d'ADN est capable de commander la polyadénylation, la terminaison de la transcription et la terminaison de la traduction de l'ARN messenger pour laquelle code cette région de codage du polypeptide.
4. Fragment d'ADN selon la revendication 1, caractérisé en ce que cette région régulatrice provient de *Pichia pastoris* NRRL Y-11430.
5. Fragment d'ADN selon la revendication 3, comprenant en outre une ou plusieurs séquences d'ADN supplémentaires obtenues à partir d'ADN de plasmide bactérien, d'ADN de bactériophage, d'ADN de plasmide de levure et d'ADN chromosomique de levure.
6. Fragment d'ADN selon la revendication 5, dans lequel cet ADN chromosomique de levure comprend une séquence d'ADN se répliquant d'une manière autonome et un gène marqueur.

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7. Fragment d'ADN selon l'une quelconque des revendications 2 à 6, caractérisé en ce que cette région de codage du polypeptide code pour un polypeptide hétérologue.
8. Fragment d'ADN selon l'une quelconque des revendications 2 à 6, caractérisé en ce que cette région de codage du polypeptide code pour l'alcool oxydase.
9. Fragment d'ADN selon l'une quelconque des revendications 2 à 6, caractérisé en ce que cette région de codage du polypeptide code pour la dihydroxyacétone synthase.
10. Fragment d'ADN selon l'une quelconque des revendications 2 à 6, caractérisé en ce que cette région de codage du polypeptide code pour le polypeptide p40.
11. Fragment d'ADN selon l'une quelconque des revendications 2 à 6, caractérisé en ce que ce fragment est sous la forme d'un plasmide hybride circulaire fermé.
12. Gène obtenu à partir de *Pichia pastoris*, codant pour l'alcool oxydase, ce gène ayant comme région régulatrice une région régulatrice comprise dans le fragment d'ADN de la revendication 1.
13. Gène obtenu à partir de *Pichia pastoris*, codant pour la dihydroxyacétone synthase, ce gène ayant comme région régulatrice une région régulatrice comprise dans le fragment d'ADN de la revendication 1.
14. Gène obtenu à partir de *Pichia pastoris*, codant pour le polypeptide p40, ce gène ayant comme région régulatrice une région régulatrice comprise dans le fragment d'ADN de la revendication 1.
15. Souche de levure transformée en transformant *Pichia pastoris* comme hôte avec un vecteur d'expression portant une matière d'ADN recombinant, dans lequel cette matière d'ADN recombinant comprend le fragment d'ADN de la revendication 3.
16. Souche de levure transformée de la revendication 15, dans lequel cet hôte *Pichia pastoris* est GS 115 (NRRL Y-15851).
17. Procédé de préparation de polypeptides comprenant le fait de cultiver la souche de levure transformée des revendications 15 ou 16 dans un milieu nutritif et d'induire l'expression en présence de méthanol, et de récupérer les polypeptides.
18. Procédé selon la revendication 17, dans lequel le milieu nutritif pour cultiver les souches de levure transformées des revendications 15 ou 16 contient du méthanol.

### 40 Revendications pour l'Etat contractant suivant : AT

1. Procédé de préparation de polypeptides comprenant la culture d'une souche de levure transformée obtenue en transformant *Pichia pastoris* comme hôte avec un vecteur d'expression portant une matière d'ADN recombinant, dans lequel cette matière d'ADN recombinant comprend un fragment d'ADN comprenant une région régulatrice obtenue à partir de *Pichia pastoris* dans laquelle cette région régulatrice répond à la présence de méthanol dans le milieu de culture avec lequel ce fragment d'ADN est en contact, dans laquelle cette région régulatrice est capable de commander la transcription de l'ARN messager lorsqu'elle est disposée à l'extrémité 5' d'un ADN qui code pour cet ARN messager, cette région régulatrice étant choisie parmi :
  - (a) la région régulatrice qui commande la transcription de l'ARN messager qui code pour la dihydroxyacétone synthétase pouvant être obtenue à partir d'un clone pPG6.0 (NRRL B-15867) du site de restriction 5'-HindIII au site de restriction 3'-XhoI;
  - (b) la région régulatrice qui commande la transcription de l'ARN messager qui code pour l'alcool oxydase pouvant être obtenu à partir du clone pPG4.0 (NRRL B-15868) du site de restriction 5'-EcoRI au site de restriction 3'-EcoRV;
  - (c) la région régulatrice qui commande la transcription de l'ARN messager qui code pour le p40 pouvant être obtenu à partir du clone pPG4.8 (NRRL B-15869) du site de restriction 5'-BamHI au site de restriction 3'-Sall;



dans lequel cette culture s'effectue dans un milieu nutritif et induit l'expression en présence de méthanol et récupère les polypeptides.

2. Procédé selon la revendication 1, dans lequel ce fragment d'ADN comprend en outre une région de codage de polypeptide, dans lequel cette région régulatrice est disposée à l'extrémité 5' de cette région de codage de polypeptide.
3. Procédé selon la revendication 2, dans lequel ce fragment d'ADN comprend en outre une séquence 3' d'ADN en aval de la région de codage du polypeptide, dans lequel cette séquence 3' d'ADN est capable de commander la polyadénylation, la terminaison de la transcription et la terminaison de la traduction de l'ARN messager pour laquelle code cette région de codage du polypeptide.
4. Procédé selon la revendication 1, caractérisé en ce que cette région régulatrice provient de *Pichia pastoris* NRRL Y-11430.
5. Procédé selon la revendication 3, dans lequel ce fragment d'ADN comprend une ou plusieurs séquences d'ADN supplémentaires obtenues à partir d'ADN de plasmide bactérien, d'ADN de bactériophage, d'ADN de plasmide de levure et d'ADN chromosomique de levure.
6. Procédé selon la revendication 5, dans lequel cet ADN chromosomique de levure comprend une séquence d'ADN se répliquant d'une manière autonome et un gène marqueur.
7. Procédé selon l'une quelconque des revendications 2 à 6, caractérisé en ce que cette région de codage du polypeptide code pour un polypeptide hétérologue.
8. Procédé selon l'une quelconque des revendications 2 à 6, caractérisé en ce que cette région de codage du polypeptide code pour l'alcool oxydase.
9. Procédé selon l'une quelconque des revendications 2 à 6, caractérisé en ce que cette région de codage du polypeptide code pour la dihydroxyacétone synthase.
10. Procédé selon l'une quelconque des revendications 2 à 6, caractérisé en ce que cette région de codage du polypeptide code pour le polypeptide p40.
11. Procédé selon l'une quelconque des revendications 2 à 6, caractérisé en ce que ce fragment est sous la forme d'un plasmide hybride circulaire fermé.
12. Gène obtenu à partir de *Pichia pastoris*, codant pour l'alcool oxydase, ce gène ayant comme région régulatrice une région régulatrice comprise dans le fragment d'ADN de la revendication 1.
13. Gène obtenu à partir de *Pichia pastoris*, codant pour la dihydroxyacétone synthase, ce gène ayant comme région régulatrice une région régulatrice comprise dans le fragment d'ADN de la revendication 1.
14. Gène obtenu à partir de *Pichia pastoris*, codant pour le polypeptide p40, ce gène ayant comme région régulatrice une région régulatrice comprise dans le fragment d'ADN de la revendication 1.
15. Procédé de la revendication 1, dans lequel cet hôte *Pichia pastoris* est GS 115 (NRRL Y-15851).
16. Procédé selon l'une quelconque des revendications 1 à 15, dans lequel le milieu nutritif pour cultiver la souche de levure transformée contient du méthanol.

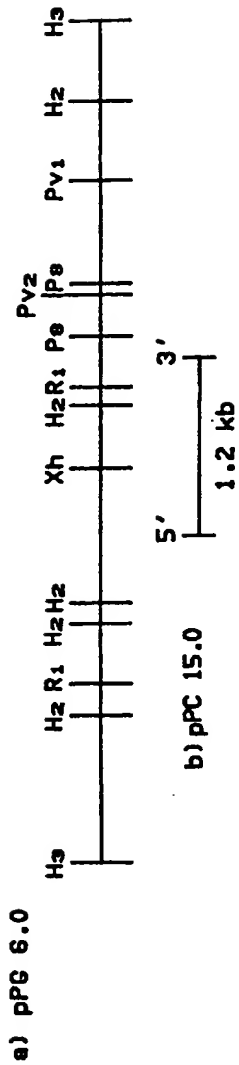


FIG. 1

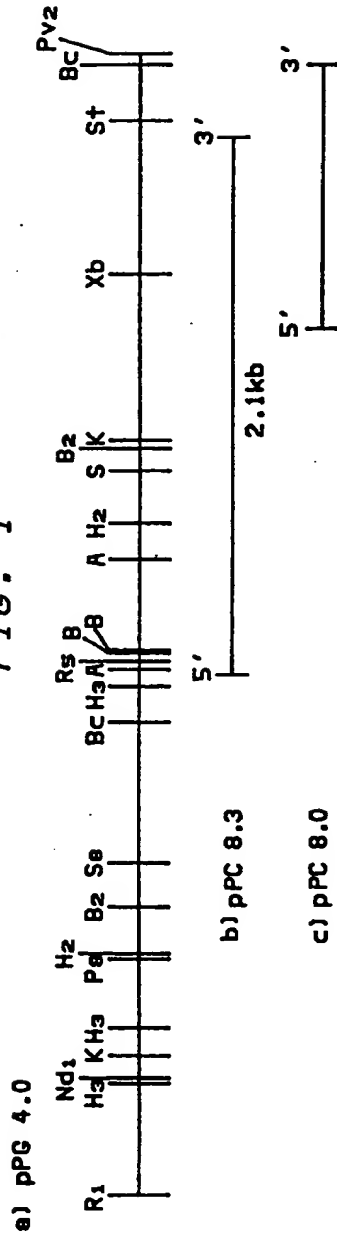


FIG. 2

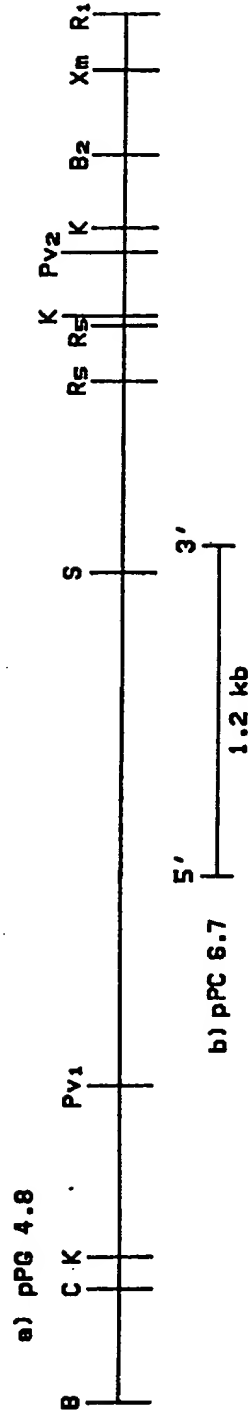


FIG. 3

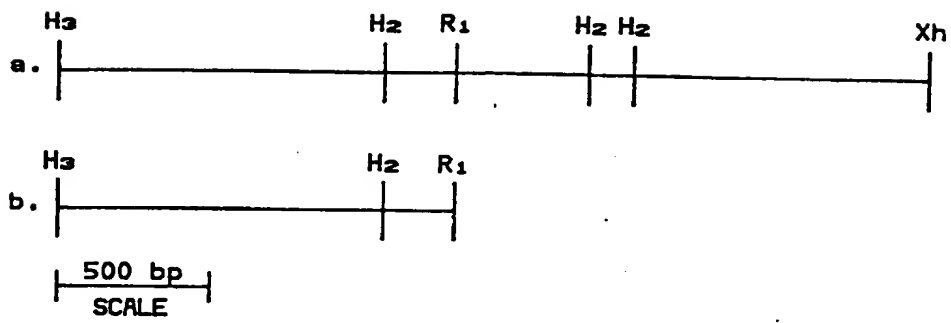


FIG. 4

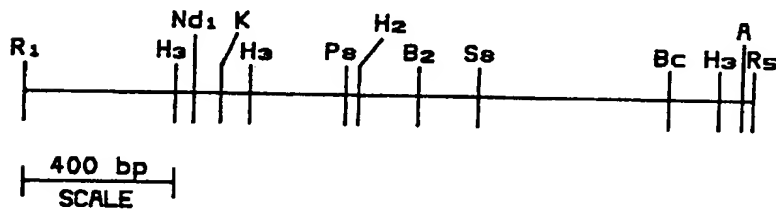


FIG. 5

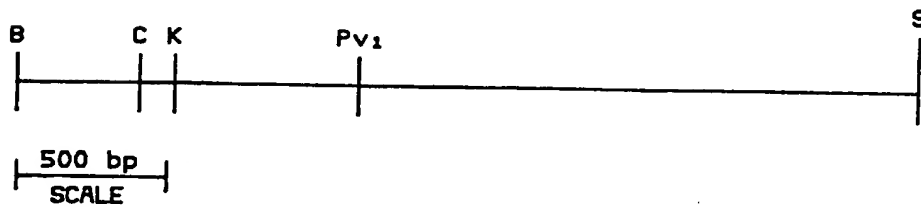


FIG. 6

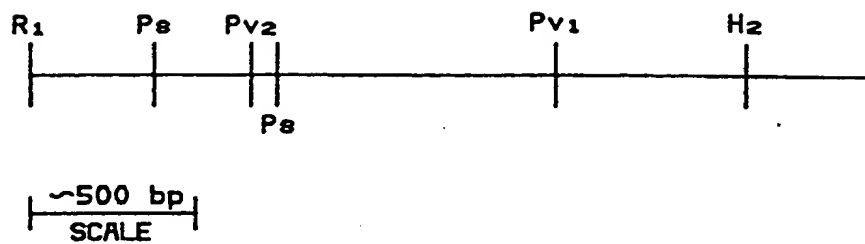


FIG. 7

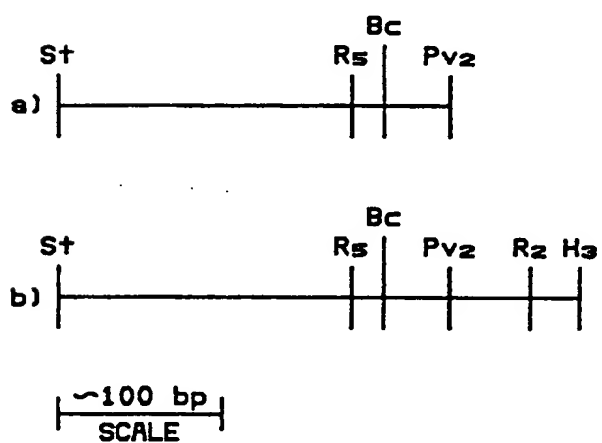


FIG. 8

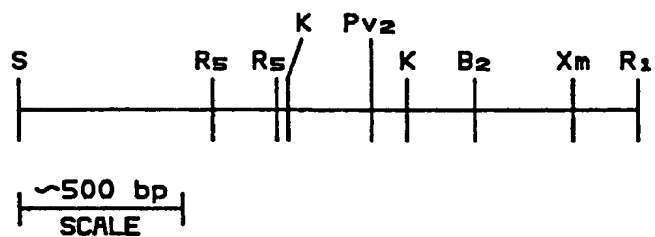


FIG. 9

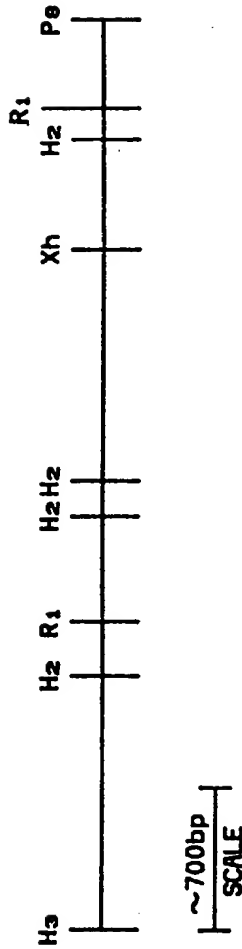


FIG. 10

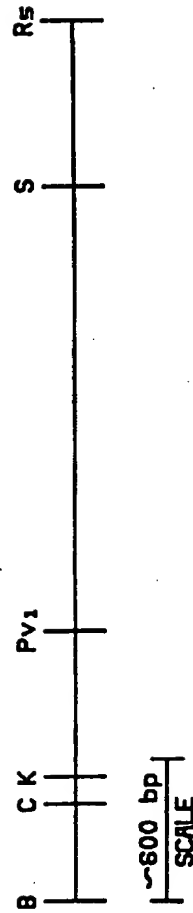


FIG. 11

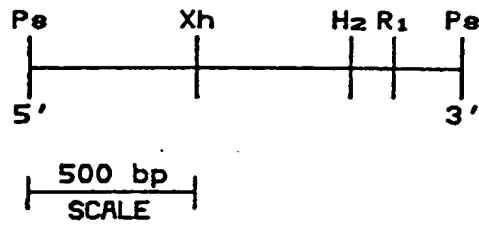


FIG. 12

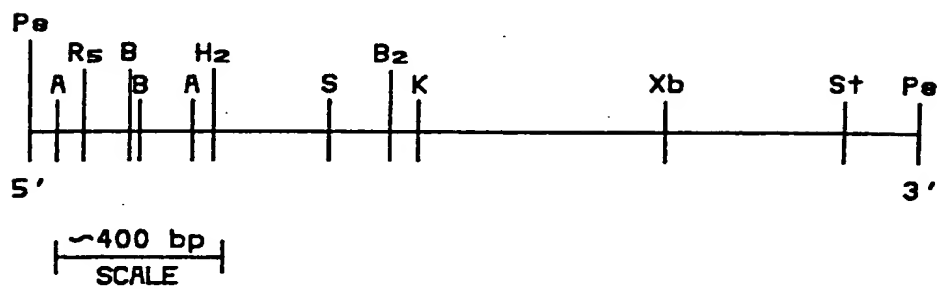


FIG. 13

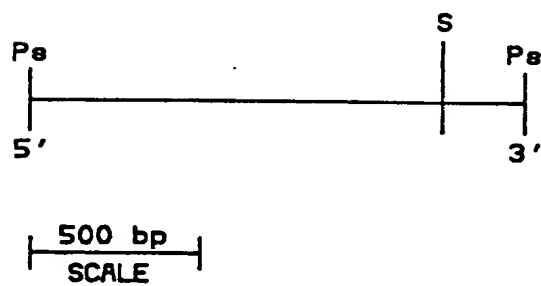


FIG. 14

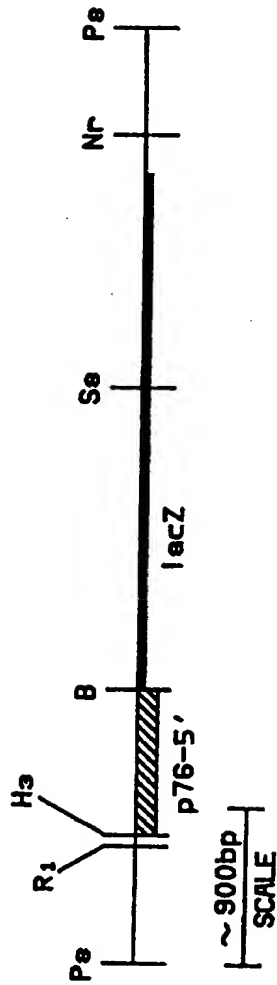


FIG. 15

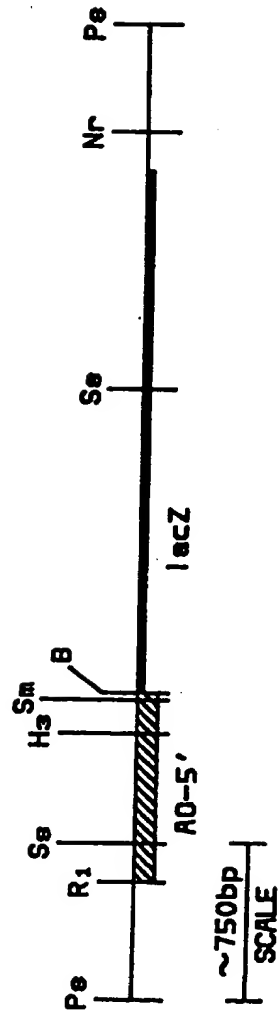


FIG. 16

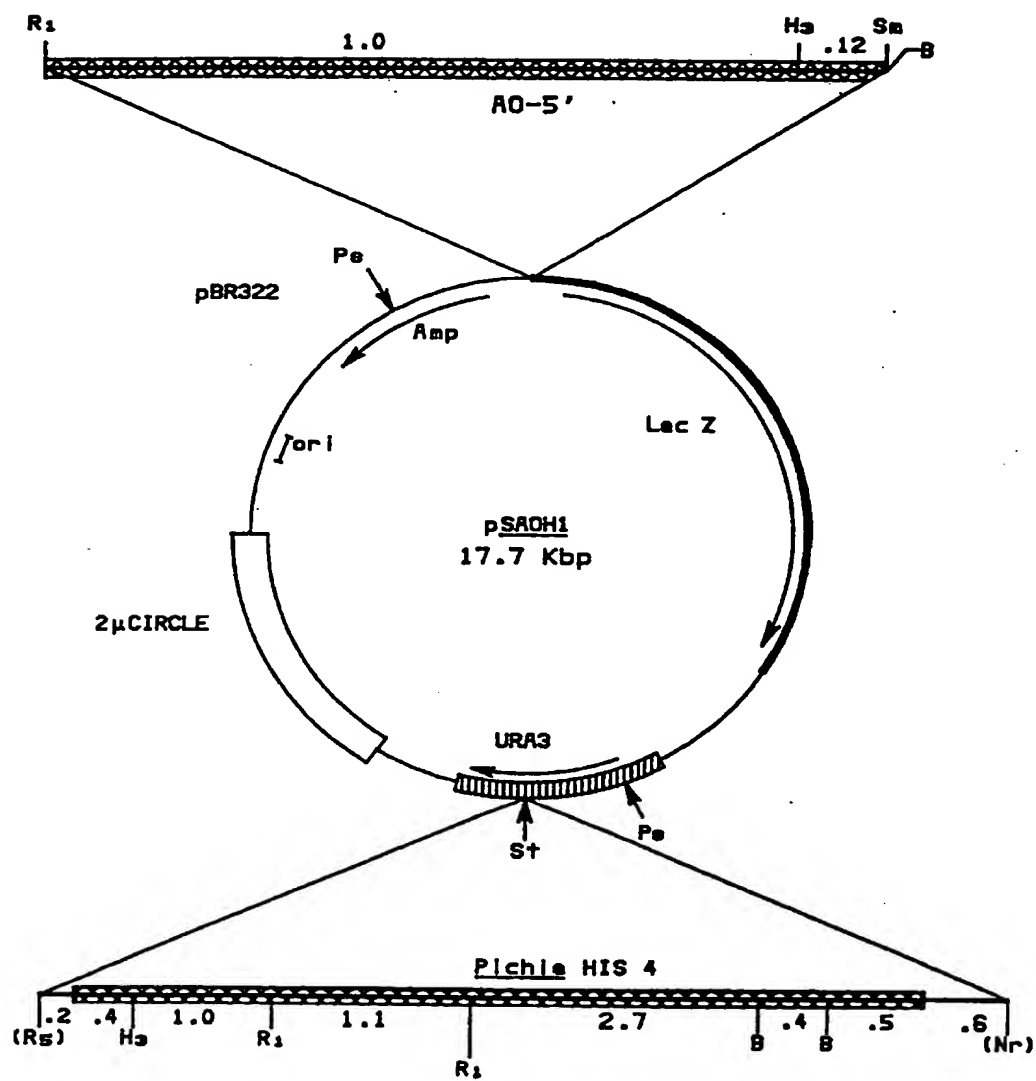


FIG. 17



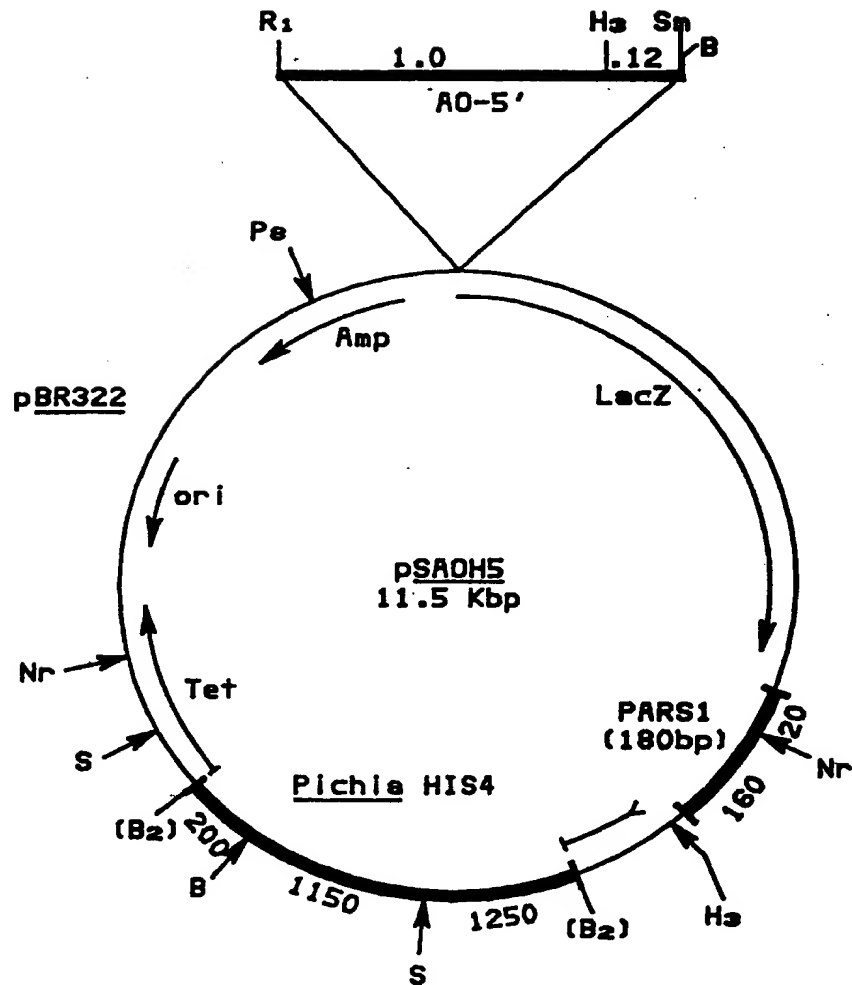
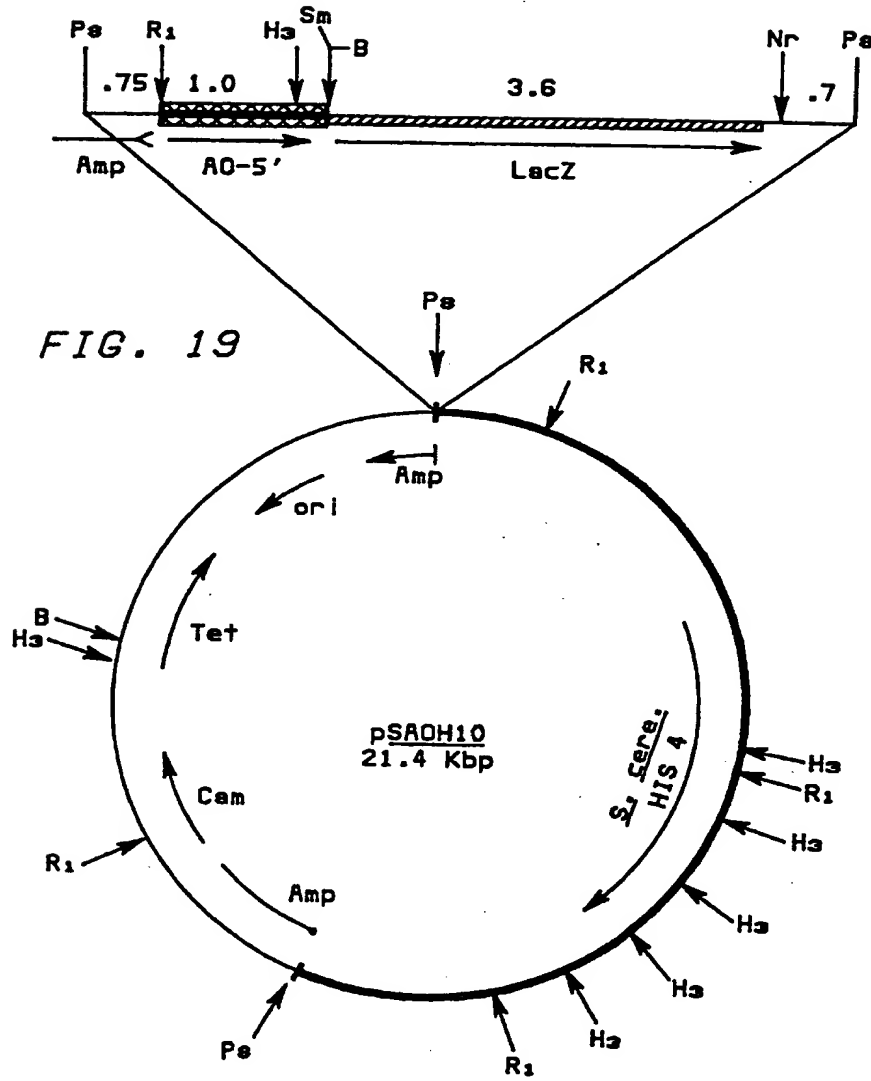


FIG. 18



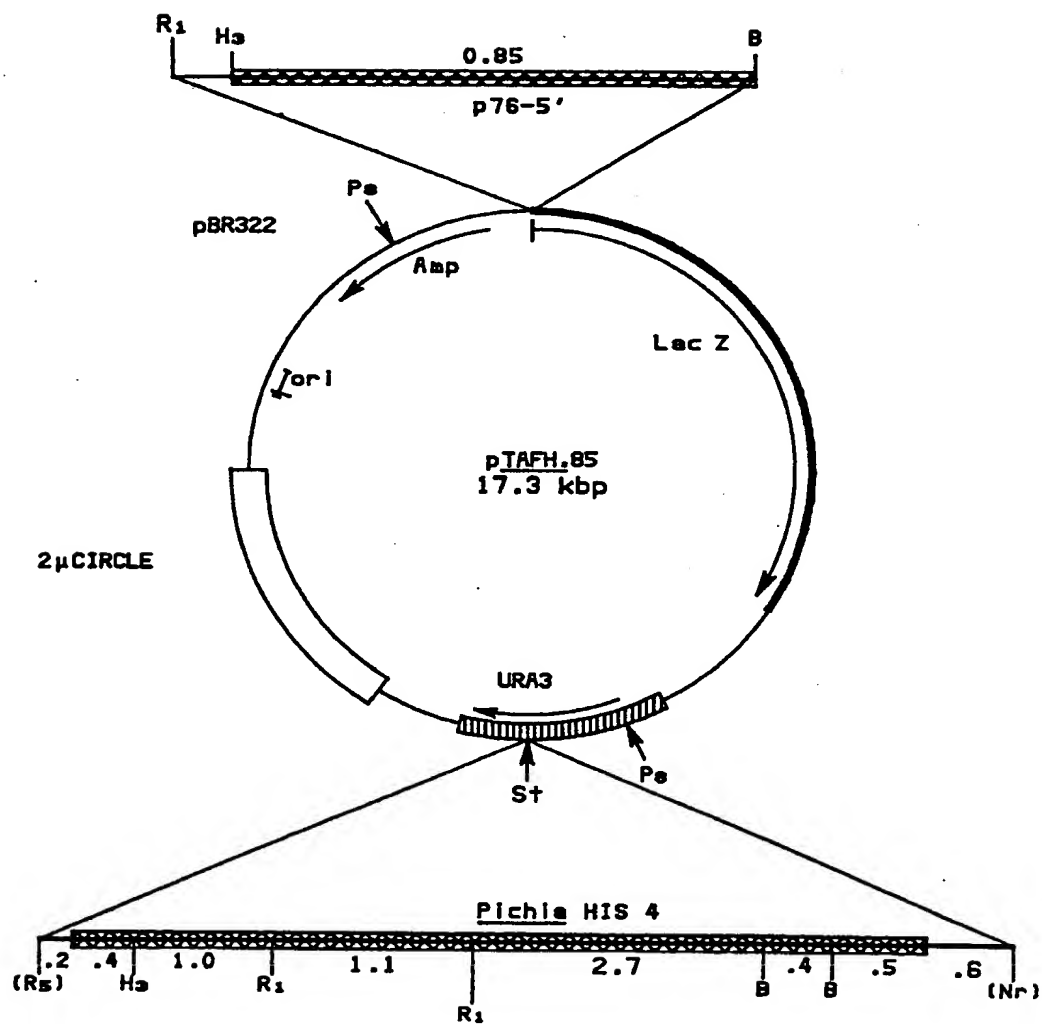


FIG. 20

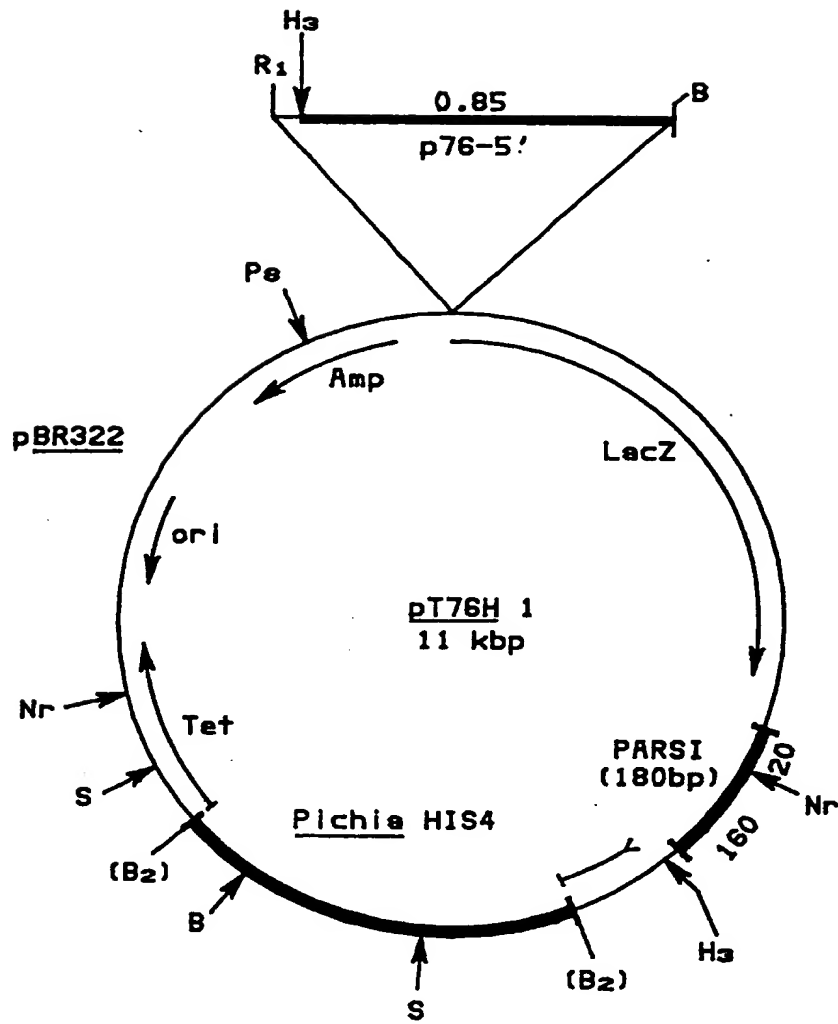


FIG. 21

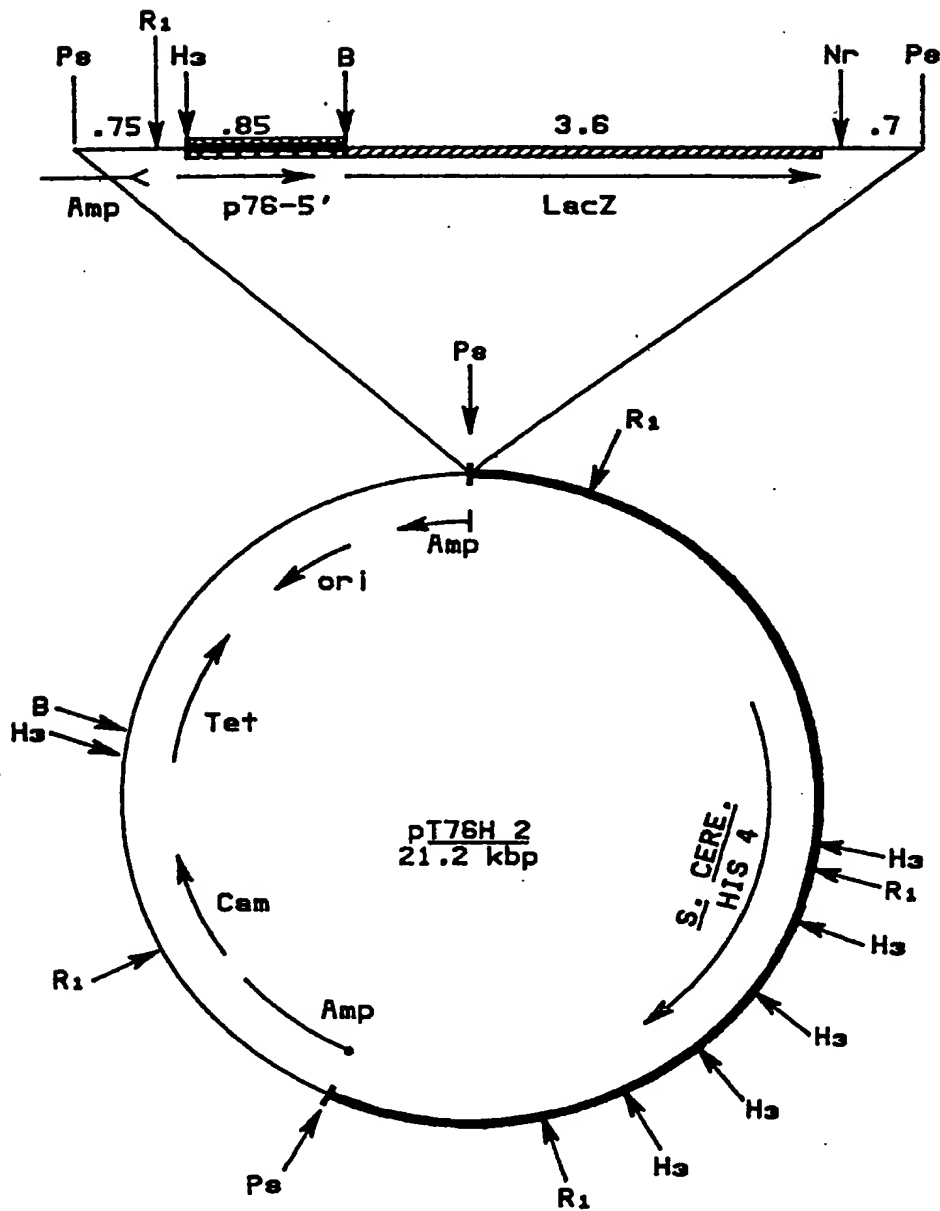


FIG. 22

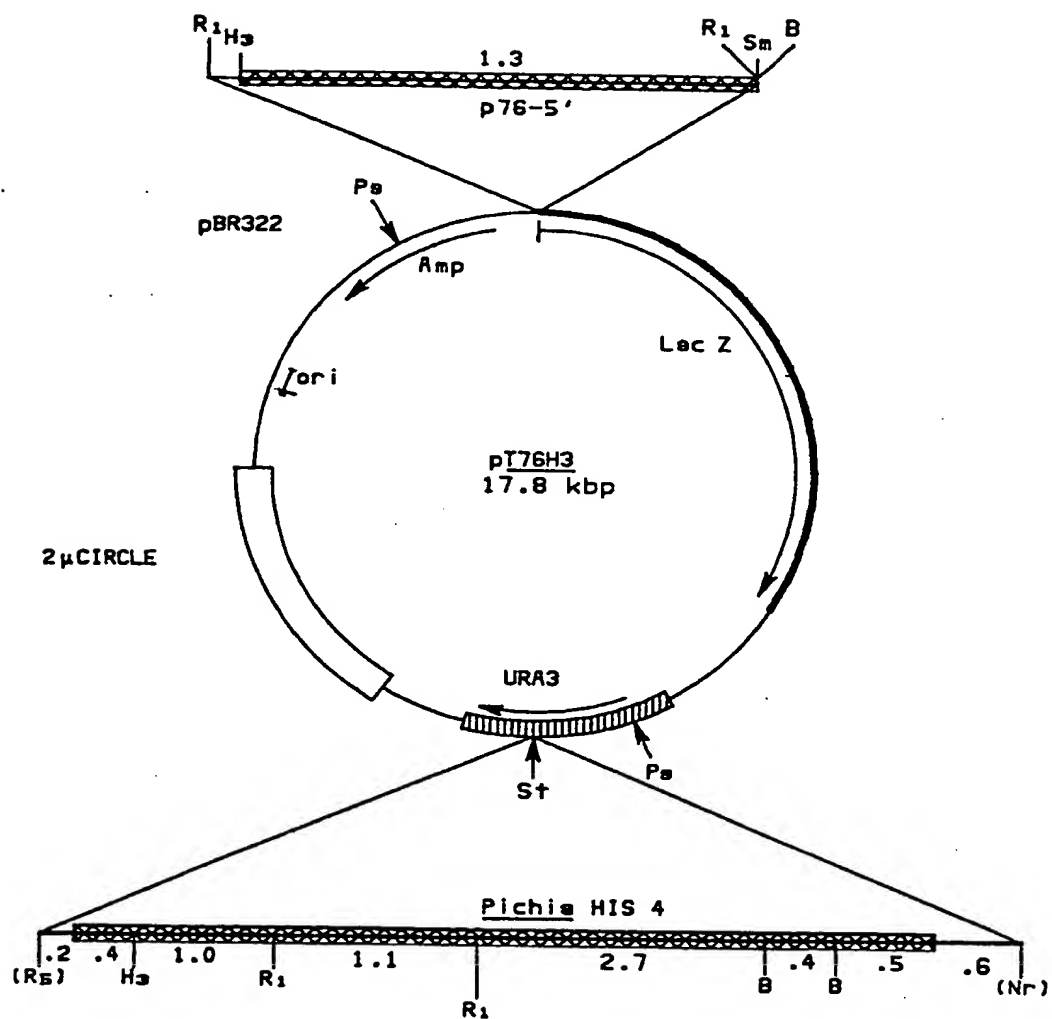


FIG. 22a

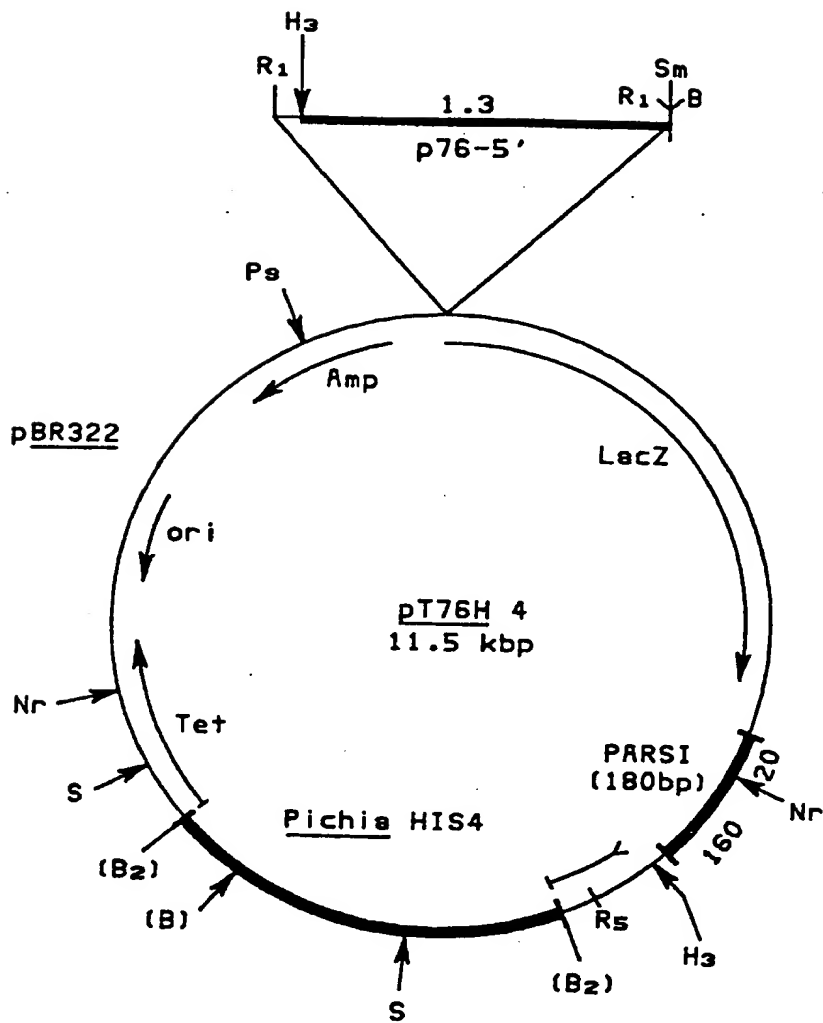


FIG. 22b

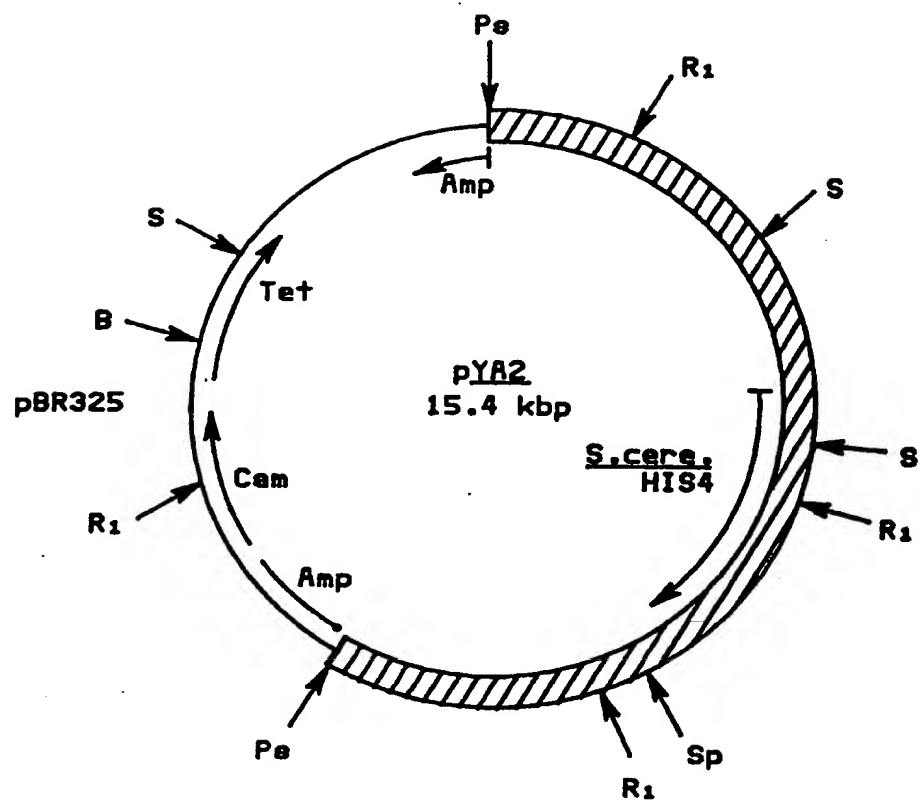


FIG. 23



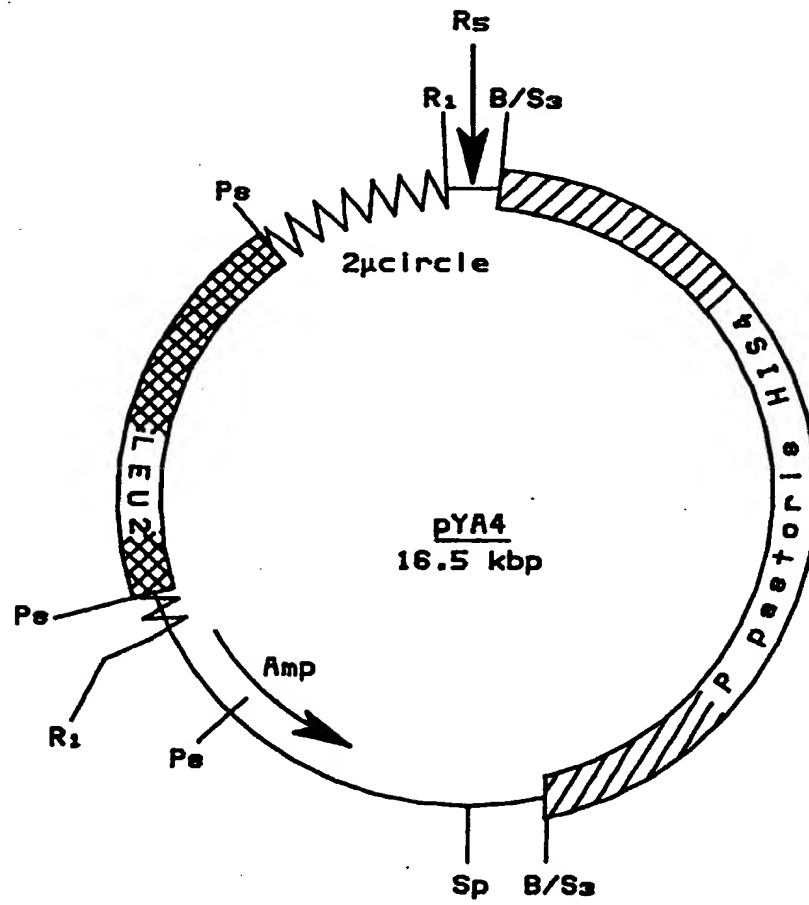


FIG. 24

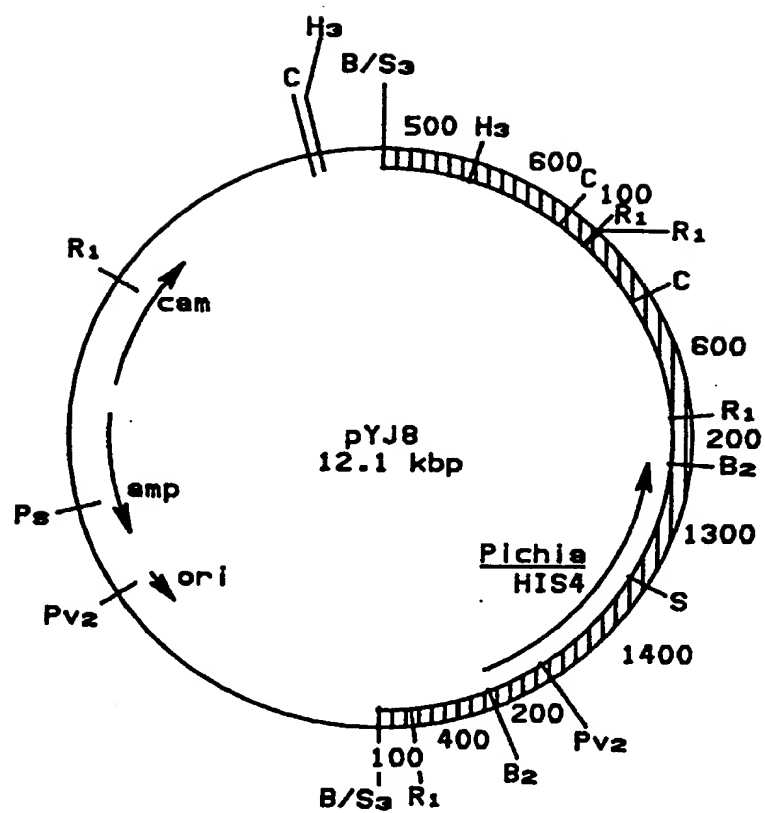


FIG. 25

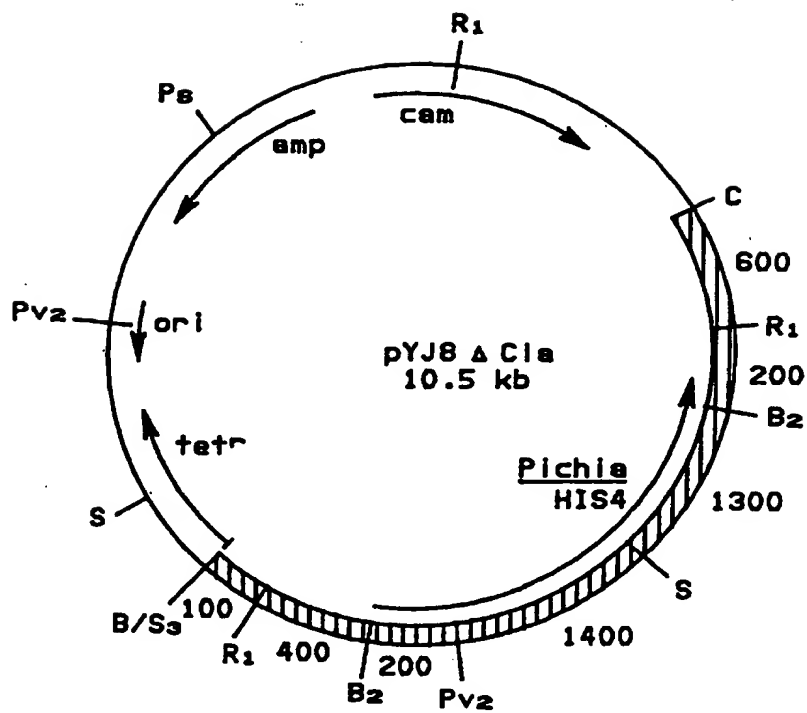


FIG. 26

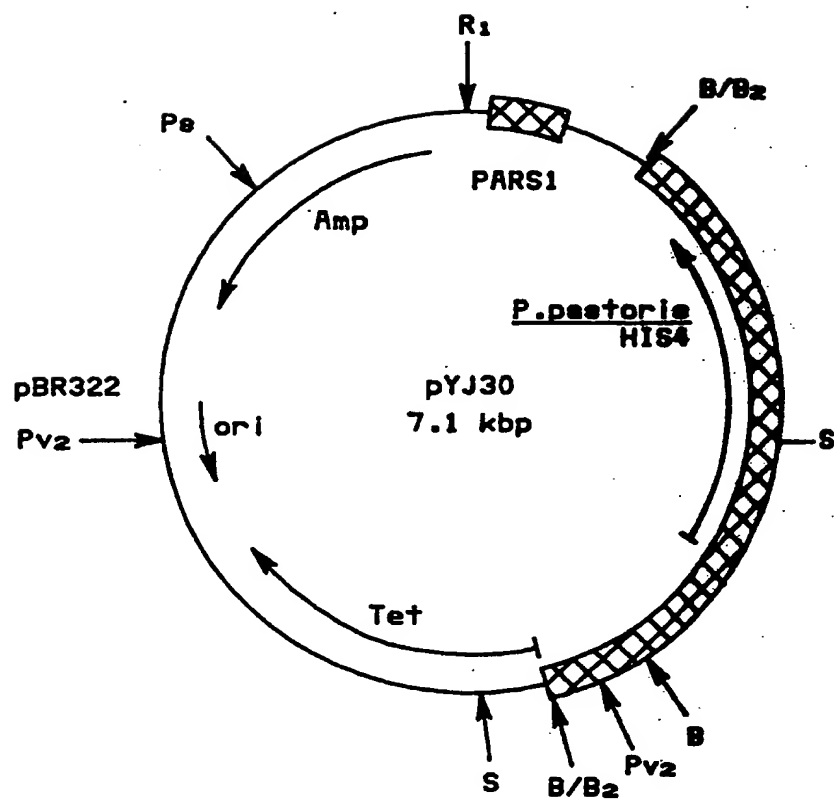


FIG. 27

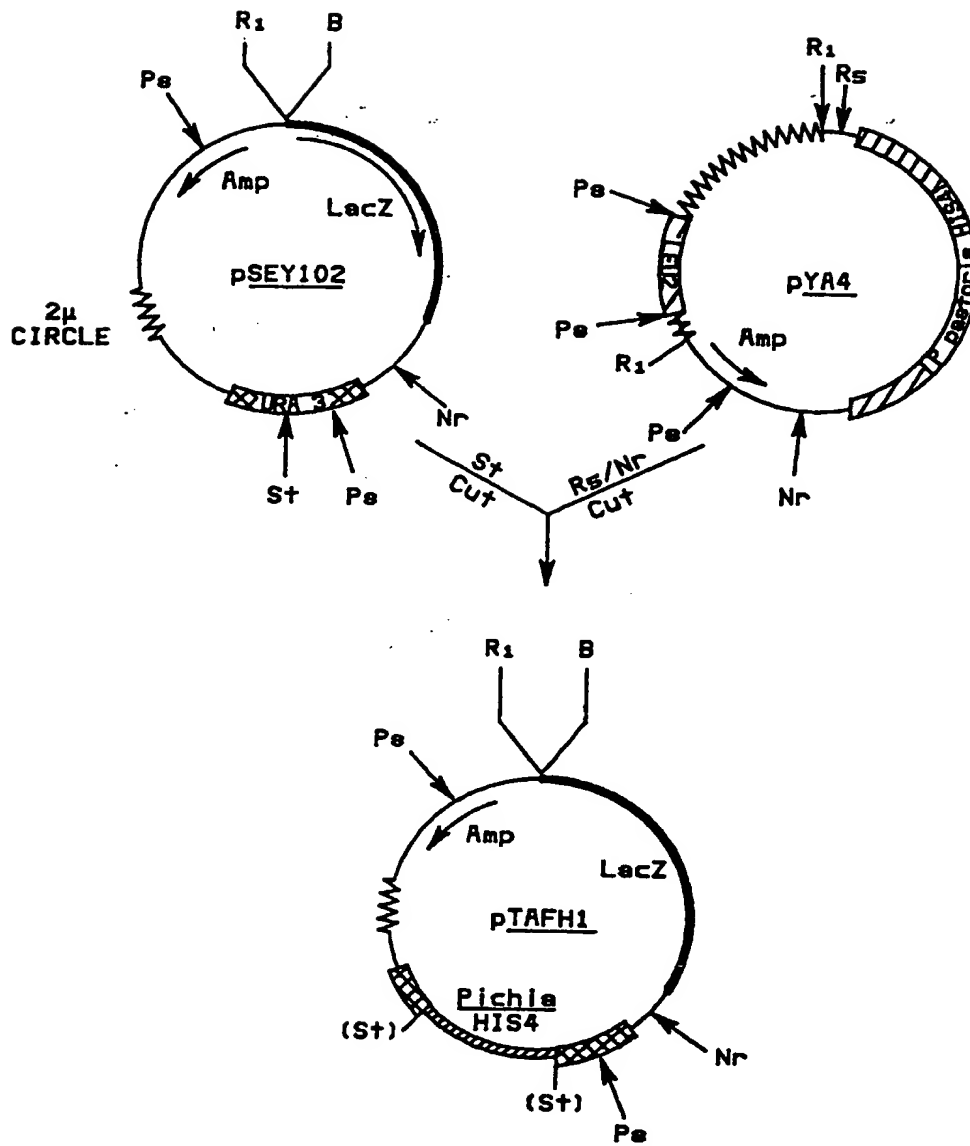


FIG. 28

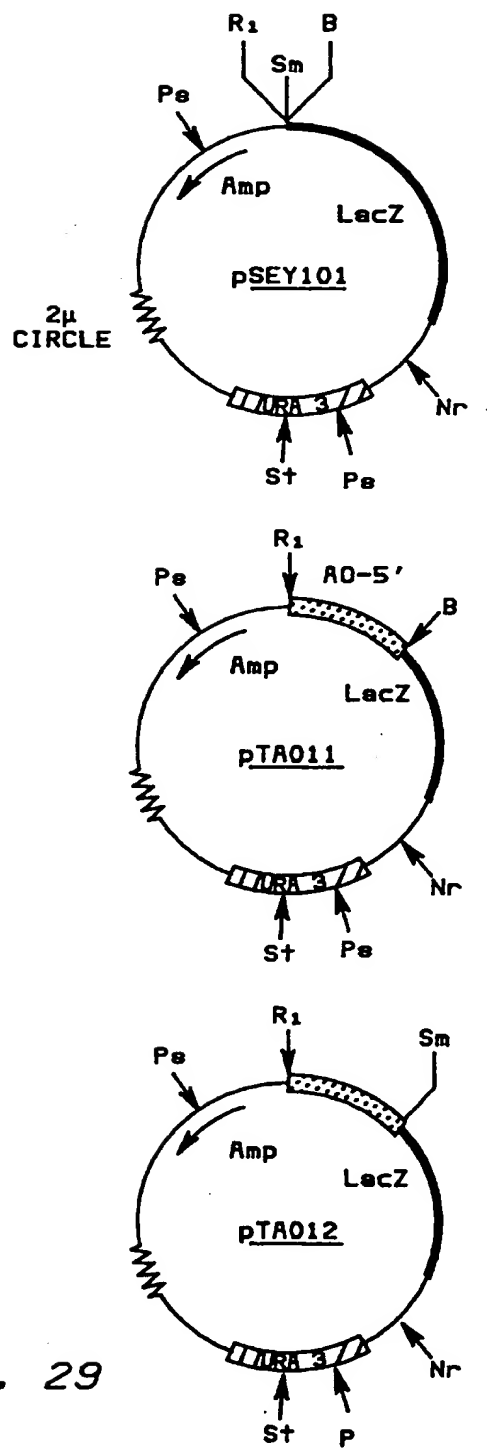


FIG. 29

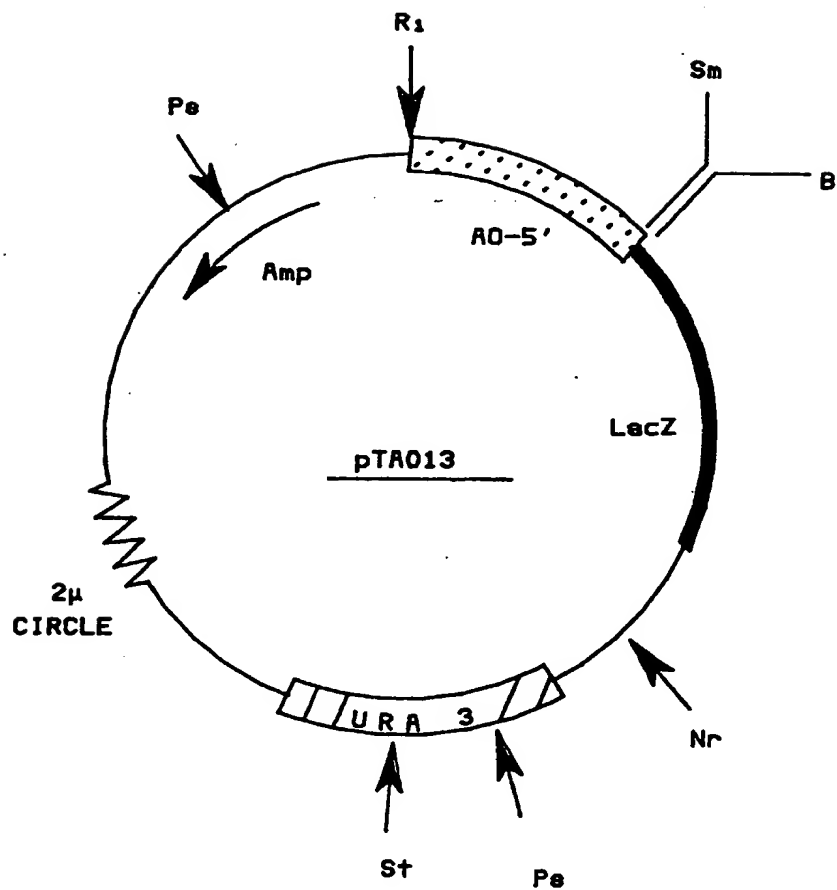


FIG. 30

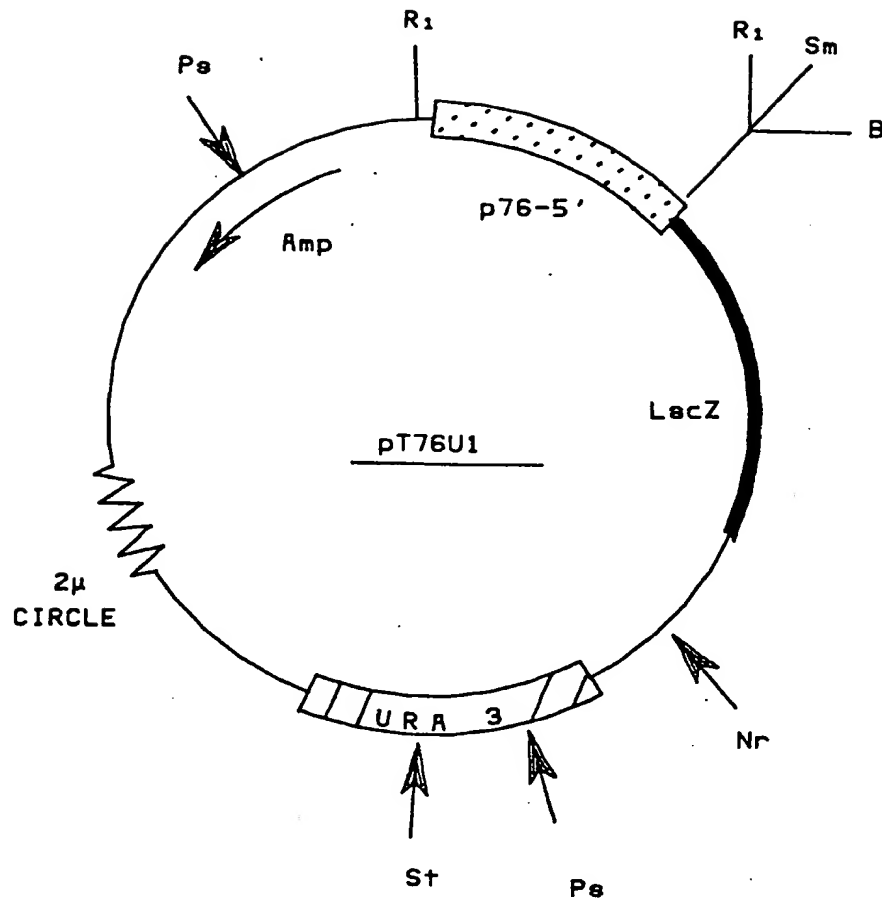


FIG. 30a



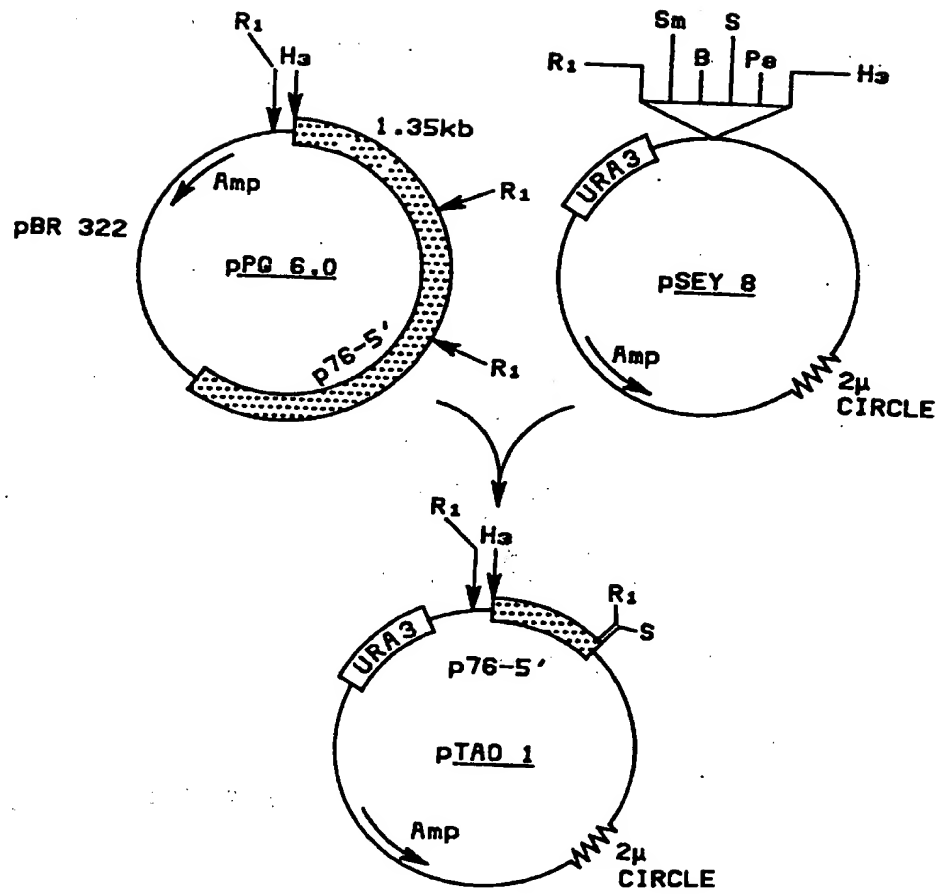


FIG. 31

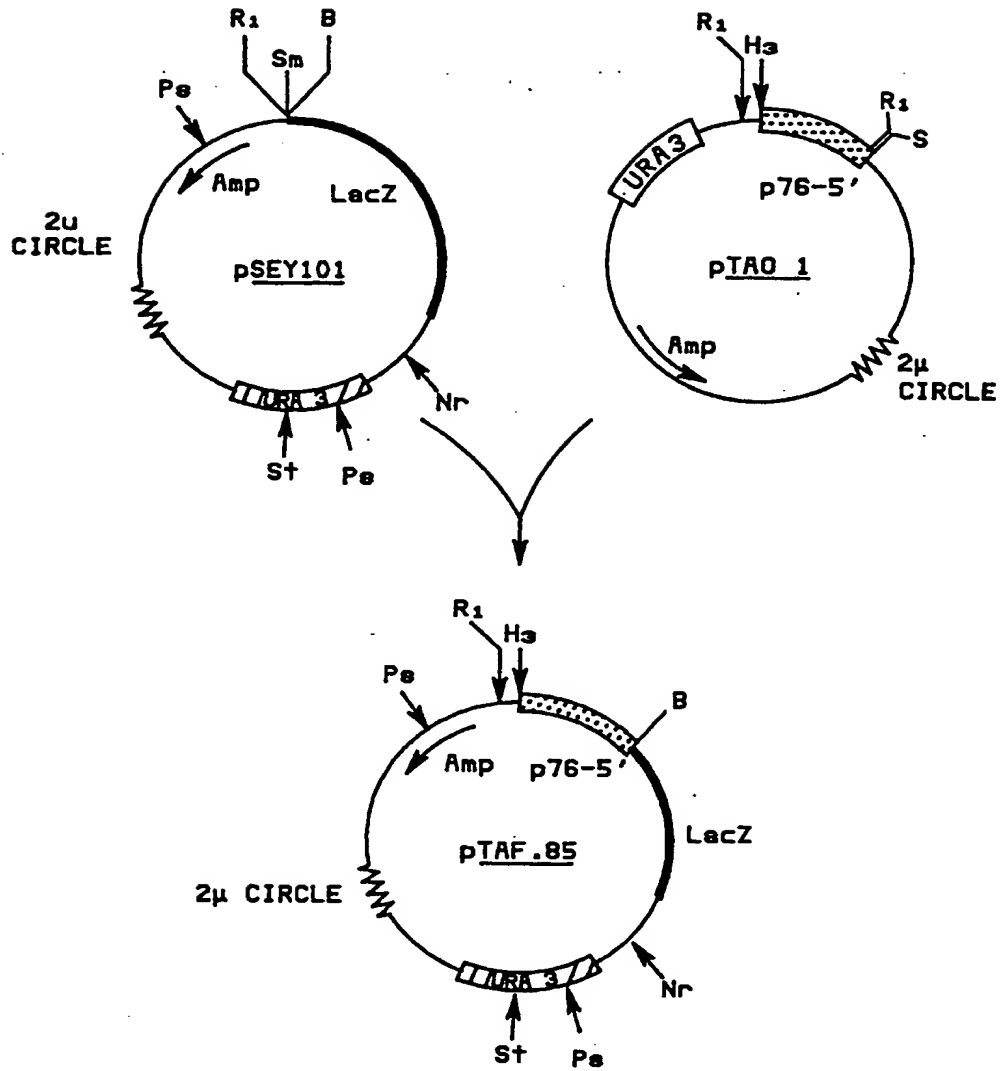


FIG. 32

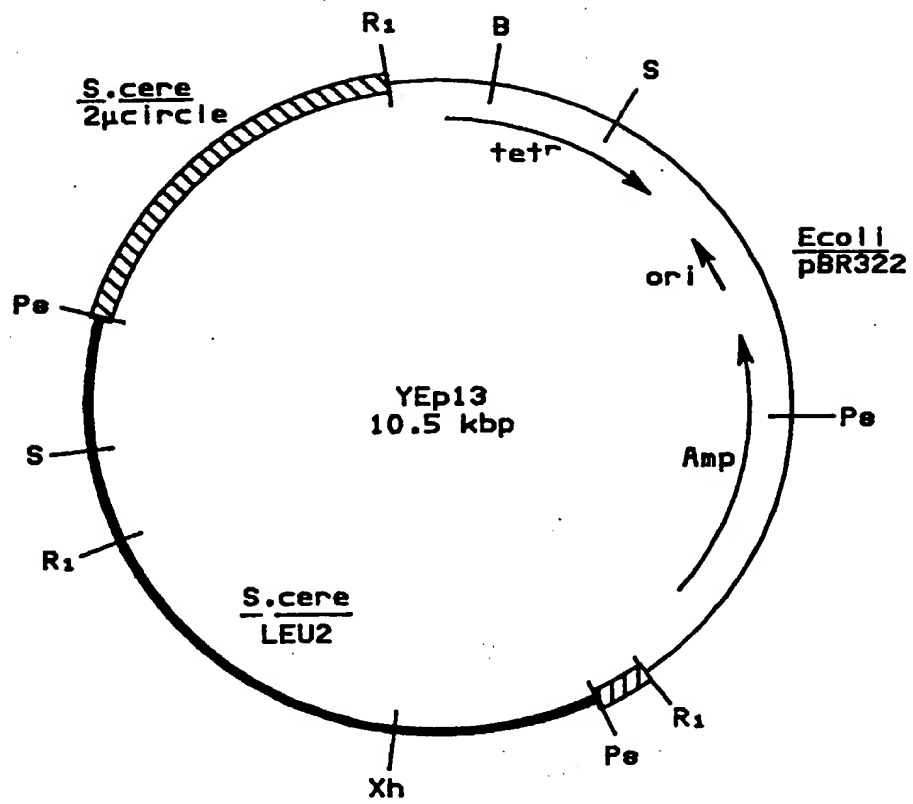


FIG. 33

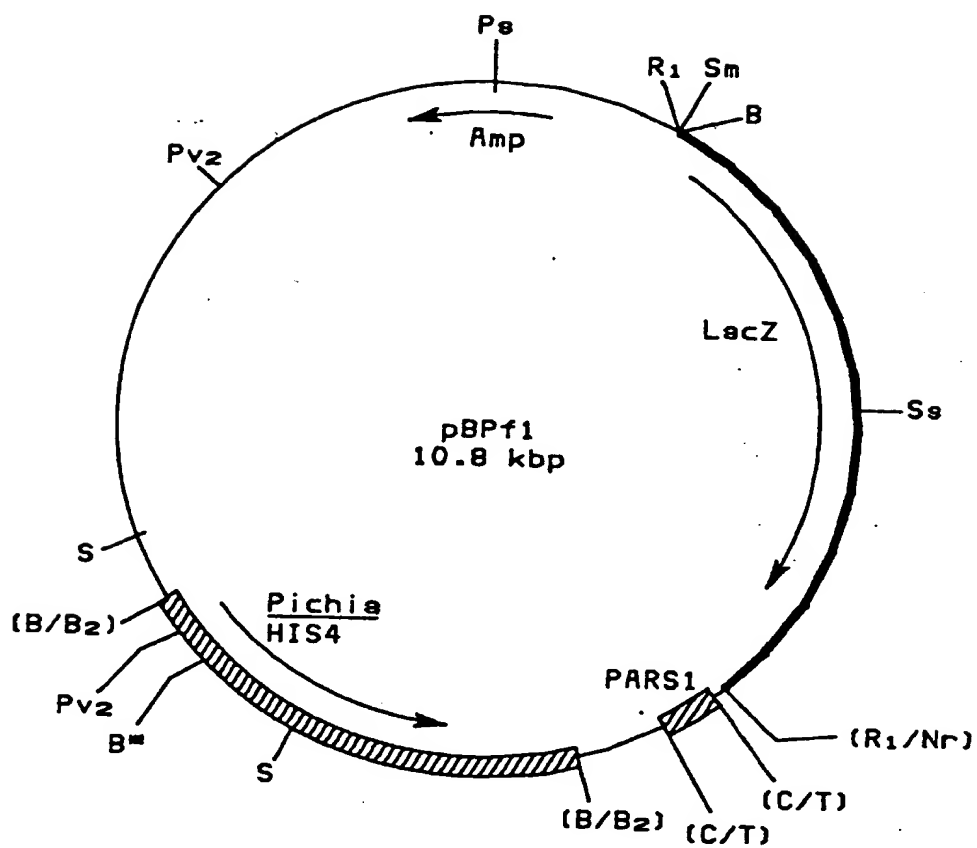


FIG. 34